& Use of Materials, Components & Finishes in Engineering Design

ngineering Materials and Design

THE UNIVERSITY OF SHEFFIELD

AUGUST 1964
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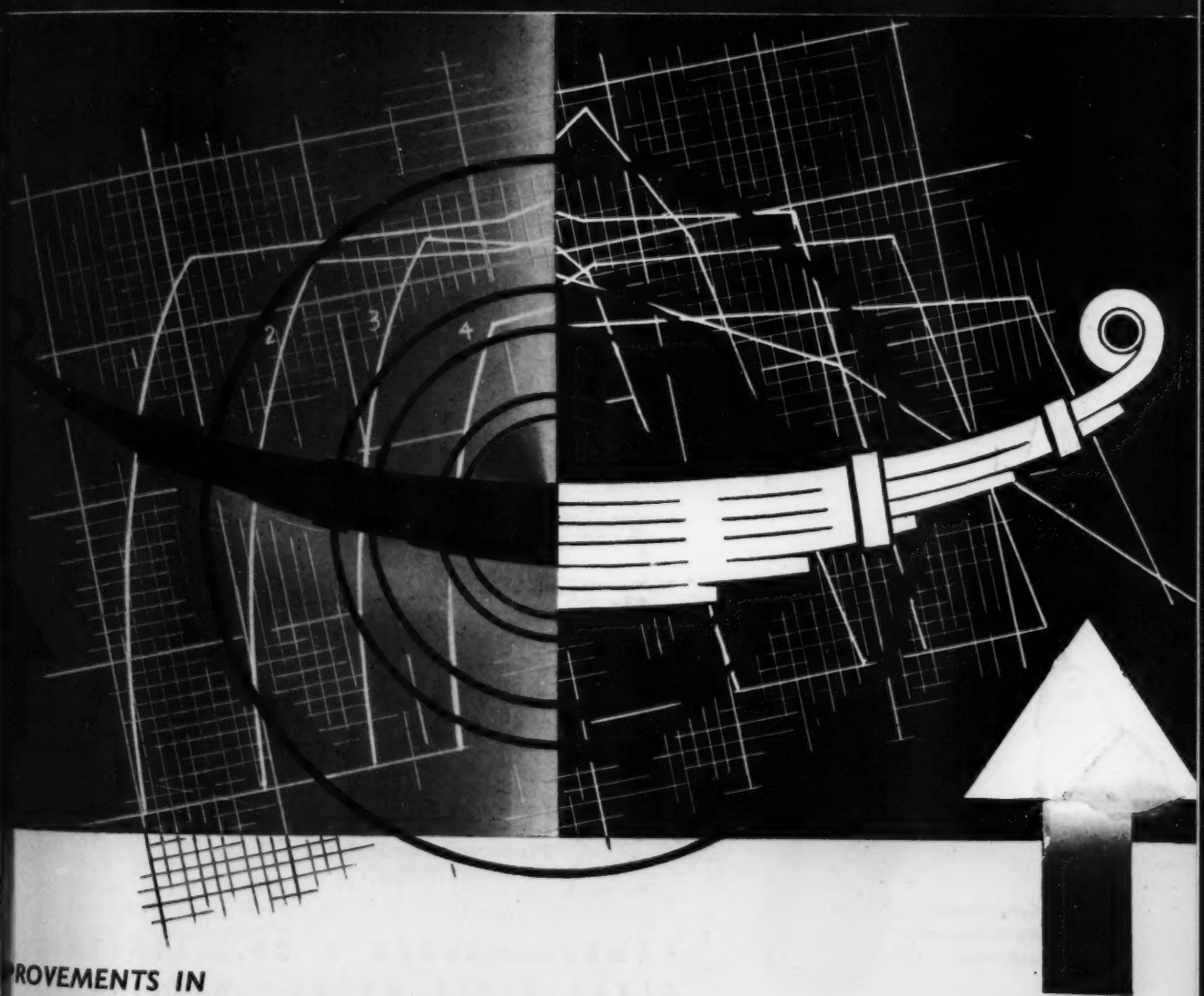

PROVEMENTS IN

Leaf Spring Design page 494

EMD 3243 for further information

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A HEYWOOD PUBLICATION

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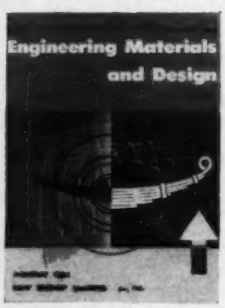

COVER: Artistic impression of the contrast between new and old designs of leaf spring. On the right is the conventional heavy spring having non-uniform stresses, and on the left the new lightweight design showing nearly uniform stresses throughout its length.

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Various means of irradiation, and properties obtainable, are dealt with.
By **T. Bain, B.Sc., A.R.I.C.,** and **W. H. T. Davison, M.A. (Cantab.), F.R.I.C.**

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Survey of present and future power units.

PROGRESS IN RAIL TRANSPORT UNIT DESIGN 484
The influence of modern materials is discussed.
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BENDING STRESSES IN NON-PRINCIPAL PLANES 492
A direct method of calculation, with a small sacrifice in accuracy, is presented.
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An improved form of leaf spring is described.
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DU NOUVEAU DANS LE DESSIN DES RESSORTS A LAMES

W. P. Yaneske page 494

En refaisant tous les calculs à partir des principes fondamentaux, on a mis au point un type amélioré de ressort à lames dont le dessin tient compte des méthodes de production les plus économiques.

PROPULSION — MÉTHODES ET APPLICATIONS

page 473

L'auteur consacre une première section à la propulsion maritime puis traite des turbines à gaz, de l'énergie hydraulique, des véhicules à suspension et à propulsion par air et de l'énergie nucléaire. Il conclut sur un examen des diverses formes de propulsion par fusée.

PROGRÈS DANS LE DESSIN ET LA CONSTRUCTION DES UNITÉS FERROVIAIRES

George McArd page 484

Après avoir étudié chacune des unités principales d'un train, l'auteur examine les derniers progrès de la production des châssis les dernières recherches sur le dessin et la construction des unités et groupes ferroviaires et les nombreux matériaux nouveaux que l'on peut utiliser aujourd'hui.

POLYÉTHYLÈNE IRRADIÉ

T. Bain et W. H. T. Davison page 468

Dans cet article, l'auteur étudie les diverses méthodes d'irradiation du polyéthylène et envisage les propriétés qui en résultent. Il traite, en détail, des films et des extrusions.

TENSIONS DE COURBURE DANS LES PLANS NON-PRINCIPAUX

A. Ormerod page 492

L'article présente une méthode directe permettant de calculer, avec une précision à peine réduite, les tensions de courbure des poutres à section angulaire dans les plans non-principaux.

Kurzreferate

NEUE BLATTFEDERKONSTRUKTION

W. P. Yaneske Seite 494

Die Entwicklung einer verbesserten Blattfederkonstruktion aufgrund grundlegender Neuberechnungen, wobei die Konstruktionsanforderungen mit ökonomischen Produktionsmethoden integriert wurden.

ANTRIEBE — METHODEN UND ANWENDUNGEN

Seite 473

Nach einer Uebersicht über Schiffsantriebe befasst sich der Verfasser mit Gasturbinen, Hydraulikantrieben, druckluftbetriebenen Fahrzeugen und Atomkraft. Der Artikel schliesst mit einer Betrachtung der verschiedenen Formen von Raketenantrieben.

FORTSCHRITTE IN EINHEITSKONSTRUKTIONEN IM EISENBAHNTRANSPORT

George McArd Seite 484

Der Verfasser gibt eine detaillierte Uebersicht der hauptsächlichen Eisenbahneinheitskonstruktionen und bespricht die neuesten Entwicklungen im Bau von Untergestellen, neue Forschungsergebnisse über Einheitskonstruktionen und einige der vielen, neuen, heute verfügbaren Baustoffe.

POLYTHENBESTRAHLUNG

T. Bain und W. H. T. Davison Seite 468

Die Verfasser dieses Artikels befassen sich mit den verschiedenen Bestrahlungsmethoden für Polythen und den hierdurch erreichbaren Eigenschaften. Filme und Fliesspresslinge werden in Einzelheiten besprochen.

BIEGEBELASTUNGEN IN NEBENEBENEN

A. Ormerod Seite 492

Eine direkte Methode zur Berechnung von Biegebelastungen in abgewinkelten Trägern in den Nebenebenen, mit verhältnismässig kleinem Genauigkeitsverlust.

Резюме

ДАЛЬНЕЙШИЙ ОБЗОР КОНСТРУКЦИИ ЛИСТОВЫХ РЕССОР

В. П. Янеске стр. 494

Более усовершенствованный вид листовой рессоры разработан на основе расчета с начальных принципов, совмещая при этом нужды конструкции с экономными методами производства.

ДВИЖУЩАЯ СИЛА — МЕТОДЫ И ПРИМЕНЕНИЕ

стр. 473

Первый раздел статьи касается морских двигателей а затем обсуждаются газовые турбины, гидро-энергия, подвешанные на воздухе и двигаемые воздухом средства передвижения и ядерная энергия. В конце статьи расматриваются ракетные двигатели.

УСПЕХИ В КОНСТРУКЦИИ АГРЕГАТОВ ЖЕЛЕЗНОДОРОЖНОГО ТРАНСПОРТА

Джордж Мак Ард стр. 484

В статье расматриваются по отдельности все главные агрегаты железнодорожного транспорта; обсуждаются новейшие развития в производстве шасси, недавняя научно-исследовательская работа в области конструкции этих агрегатов и большое количество имеющихся теперь новых матерьялов.

ИРРАДИИРОВАННЫЙ ПОЛИЭТИЛЭН

Т. Бейн и В. Х. Т. Дэвисон стр. 468

В этой статье обсуждаются различные методы иррадиации полиэтилэна и полученные в результате свойства. Пленочные и экструзионные виды расматриваются в подробностях.

ИЗГИБАЮЩЕЕ НАПРЯЖЕНИЕ В НЕОСНОВНЫХ ПЛОСКОСТЯХ

А. Ормрод стр. 492

Приводится прямой метод, позволяющий с незначительной потерей точности, вычисления изгибающего напряжения угольных сегментов балок согнутых по неосновным плоскостям.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Nitriding Titanium

IMPROVED AIRCRAFT ENGINE PERFORMANCE increases the demand on the durability of metals used for many components where the material must resist galling and wear between surfaces in sliding contact, must have good resistance to impact and to salt water corrosion, be light in weight and exhibit good machinability. The U.S. National Bureau of Standards have found that nitriding gives a desirable high hardness to the surface of commercially pure titanium, although it has an adverse effect on the 6 per cent A1, 4 per cent V titanium alloy. Titanium has inherently excellent salt water corrosion resistance and also a strong affinity for nitrogen, so it was a logical choice for a starting material. The alloy containing 6 per cent aluminium and 4 per cent vanadium has recently come into widespread use, and is therefore of particular interest.

After the nitriding in pure nitrogen, analysis showed that the unalloyed metal forms a uniformly thick, hard case with a sharp line of demarcation between case and core. The nitride surface layer that forms on the Ti-6A1-4V alloy is thinner than that which forms on the unalloyed titanium, and, in addition, elongated nitride grains form in the alloy and penetrate into the core. The impact strength of the pure titanium, as determined by transverse impact tests on un-notched specimens, was found not to be impaired as a result of the nitriding, but the alloy exhibited a serious reduction in its impact resistance—the elongated nitrided grains in the alloy apparently act as stress raisers to reduce impact strength.

The uniformly thick, nitrided case on the unalloyed titanium was found to consist of a surface film 0.0005 in. thick, covering a principal layer of 0.004 in., on specimens treated for 48 hours. The total case thickness increased with increase in nitriding time, following a parabolic law, and reached a thickness in excess of 0.008 in. in 168 hours. This behaviour is contrary to that previously observed by other investigators, who found that titanium, nitrided in ammonia, attains a maximum case of approximately 0.004 in., and that further treatment reduces case thickness.

Rubber Tyres and Disc Brakes for Cranes

WHAT WAS DESCRIBED as " probably one of the last significant vehicles to change from steel wheels to rubber " was demonstrated last month at Albert E. Reed's paper mills at Aylesford, Kent. Two overhead travelling cranes believed to be the first of their kind in the world to run on pneumatic tyres are the result of co-operation between W. S. Atkins & Partners, consulting engineers, and Strachan & Henshaw, specialist crane manufacturers.

The cranes run on smooth concrete runways, dispensing with the traditional gantry rails, and each end carriage is supported by five wheels fitted with normal Michelin X commercial vehicle tyres and two horizontally mounted solid tyred wheels which bear on the sides of the concrete runways to keep the cranes running in a straight path. The solid tyres are of natural rubber fairly heavily reinforced with carbon black.

Disc brakes are fitted to two of the pneumatic wheels of each end carriage assembly, and a 7.5 h.p. electric motor drives on to a third pneumatic wheel through reduction gearing.

The cranes, which have a nominal span of 69 ft. 6 in. and a lifting capacity of two tons (this may be increased to three tons by the installation of a larger hoist motor), have a maximum speed of 400 ft. per minute.

Problems associated with the severe impact on concrete of normal steel wheeled cranes, skew-wise motion and derailment in extreme cases, vibration and jolting have been solved by the introduction of the rubber tyred wheels; it was shown that such tyres ran smoothly over gaps and inaccuracies, and the greatly improved steering characteristics resulted in appreciable increase of speed with a saving in maintenance costs.

Wider Scope for Stainless Steel

VASTLY BIGGER MARKETS for stainless steel were foreshadowed by the opening, in May, of the new Balfour Group chemical engineering development centre at Leven, Fife, by Mr. John Maclay, Secretary of State for Scotland. In this new centre, which will cost £50,000 a year to operate, there is a comprehensive series of laboratories integrated with a complete installation of pilot plant embodying all the main types of processes and equipment in use in the chemical industries today.

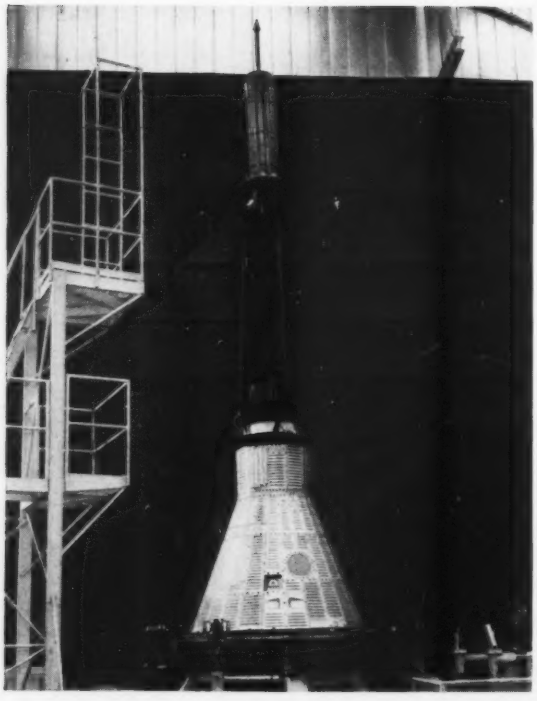
Mr. W. L. Burns, chairman of the Balfour Group, said on the opening day that stainless steel was being used increasingly by chemical engineers because of its resistance to attack by so many chemical materials. The expansion of chemical engineering that would result from the opening of the development centre would create an even bigger demand for stainless steel. "We are, however, fully aware of its limitations," he said, "and stainless steel is therefore under constant and careful study in our corrosion laboratory."

Mr. W. S. Johnston, assistant chief draughtsman of the Balfour Group, said that such things as stainless steel pipe flanges, supplied in large quantities to the Group by William Oxley and Co. Ltd., Rotherham, found their way, through chemical engineering, into countless other industries, from food processing to atomic power. "In fact," he said, "so much stainless steel is now being used in chemical engineering where mild steel was formerly used, that demand often exceeds supply and sometimes this could be the only thing that would delay us in completing a contract."

White Metal Bearing Corrosion

CORROSION OF WHITE METAL BEARINGS in marine steam turbines has been a problem for many years. It has taken the form of an attack on the tin matrix. Tin oxide, a very hard material, is a major component of the corrosion product, in some cases forming to a depth of 0.010 to 0.015 in. and resulting in flaking with subsequent bearing failure. Similar, but much less severe, corrosion has been known to occur in land based turbines. Work by research chemists of the Wakefield Castrol Group, investigating this problem, has now revealed that the possible cause of the corrosion is stray electric currents. Electrolytic corrosion of tin in a normal steel tin system could not occur, since the steel would be the anode, but by applying a low electric potential (1.5 volts) to a white metal/steel combination immersed in a very weak salt solution the arrangement has been reversed, the white metal being transformed into the anode.

In laboratory experiments, a corrosion layer 0.0015 in. thick has been produced in a 40 hour period. This, by microscopic examination and X-ray diffraction analysis, was seen to be identical with that occurring in service. Alternating current has produced a similar effect but at a very much slower rate. That the problem has become more common in recent years may well be explained by the increasing use of electrical and electronic equipment, including radar, although the effects of these devices on the electrical conditions in propulsive machinery are not yet fully known.

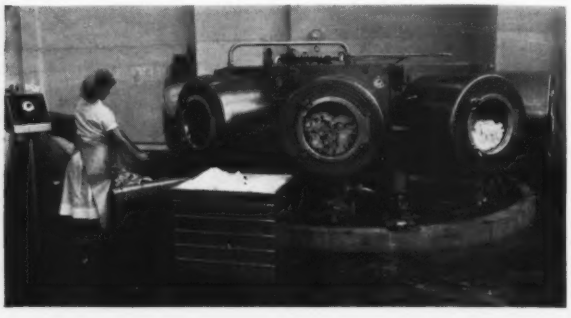


SPACE CAPSULE

One of the first photographs of the project Mercury space capsule instrumented for escape system tests. It was delivered recently to the National Aeronautics and Space Administration by McDonnell Aircraft. The pylon shown on top of the capsule incorporates the escape system.

TURRET WASHING MACHINE

The first Carousel contraflow washing unit to be used in a British hospital has been installed by Baker Perkins Ltd. Each of these machines consists of ten individual end-loading washers arranged in a circle, and connected in such a way that a continuously-flowing stream of water is passed from one machine to another.

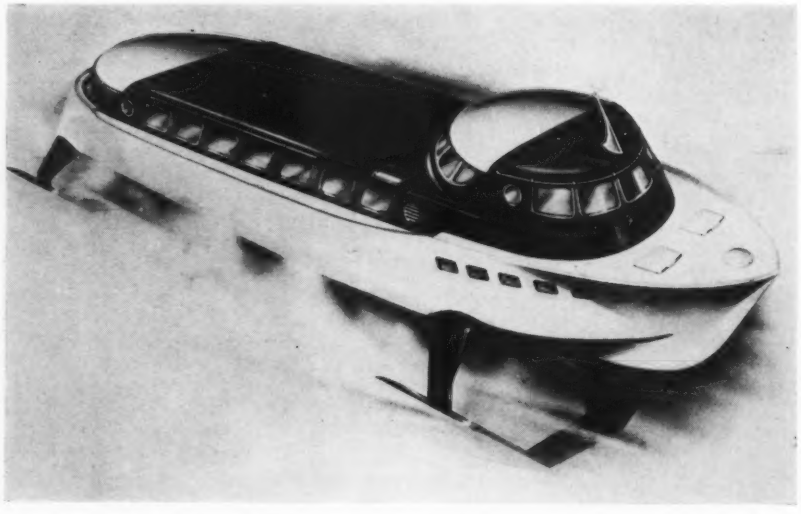


PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

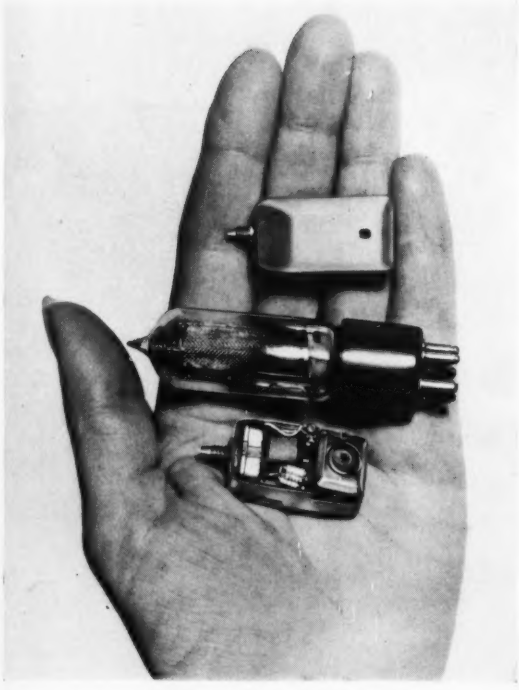
DESIGN ELEGANCE IN PLASTICS

The Aristocrat FL50 telephone now being-made by Autophone Ltd. is moulded from Styron 475 polystyrene. The outer dial ring is placed to facilitate easy letter and figure recognition and the cord, which is only 12 in. long in the rest position, will stretch to over 4 ft.



HYDROFOIL FERRY BOATS

A 28-ton high-speed hydrofoil ferry boat made by the Waste King Corp. is designed to carry 93 passengers at speeds of 40 knots over 200 miles in seas up to 8 ft. high. It is powered by a single engine and will have fixed foils to give low initial cost and minimum maintenance.

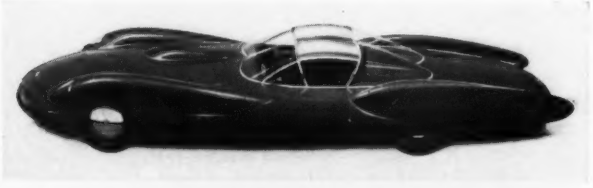


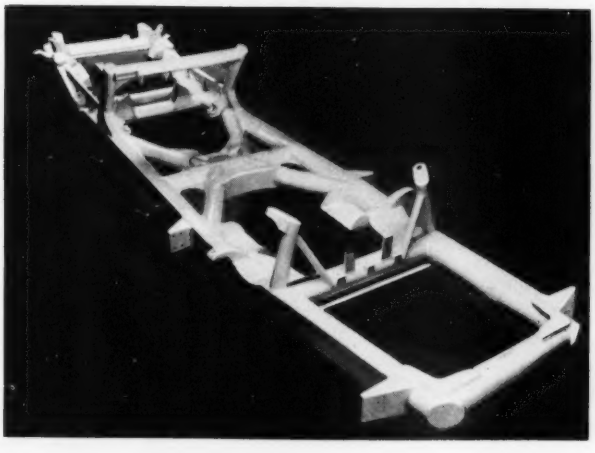
ELECTRONICS PROGRESS

The left-hand picture illustrates the progress in miniaturisation which has been made in the last 20 years. The Sonotone model 66 hearing aid is shown at top and bottom, with in the middle one of several valves used in a hearing aid of 1937.

LUXURY SPORTS CAR

The Argonaut Smoke, developed in the U.S., displays a pleasing combination of modern lines with established engineering design. It incorporates a tubular chassis (lower picture) to provide a low centre of gravity and overall rigidity, thus relieving the aluminium body from stress loads. Maximum speed is said to be about 200 m.p.h.



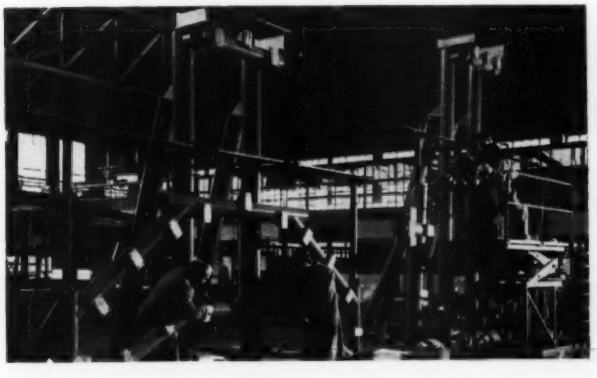


TEACHING MACHINE

Seen above is the Auto-Tutor, developed by United States Industries Inc. for the teaching of processes. Instructional material can be put on film strip or film and incorporated in 10,000 images handled by the tutor.

BRITANNIC JIGS TAKE SHAPE

Construction of the steel jigs in which the SC5 Britannic freighter will be built is well under way at Short Bros. & Harland's Belfast factory (see below). The jigs are amongst the largest ever erected in Britain and consist of mild steel tubes varying in diameter from 3 to 10¾ in.



NICKEL ALLOY STEELS

ensure reliability in mechanical drives

TYPICAL CORE MECHANICAL PROPERTIES OF

EN36

ARE GIVEN BELOW:

The Hobbs automatic transmission, designed and made by Hobbs Transmission, Ltd., Leamington, is applicable to many types of industrial drives although designed primarily for use on motor cars.

One of the best known steels used for motor car gears, the 3 per cent nickel-chromium-molybdenum EN 36 case-hardening steel, was chosen for this unit. Service experience has shown that EN 36 has the properties needed to withstand the stresses to which the gears are subjected.

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
1¼" dia.	Oil quenched 780°C.	72·0	19	69
2¼" dia.	Oil quenched 860°C.	62·7	19	67
3" dia.	Oil quenched 780°C. Oil quenched 860°C. Oil quenched 780°C.	59·7	22	72

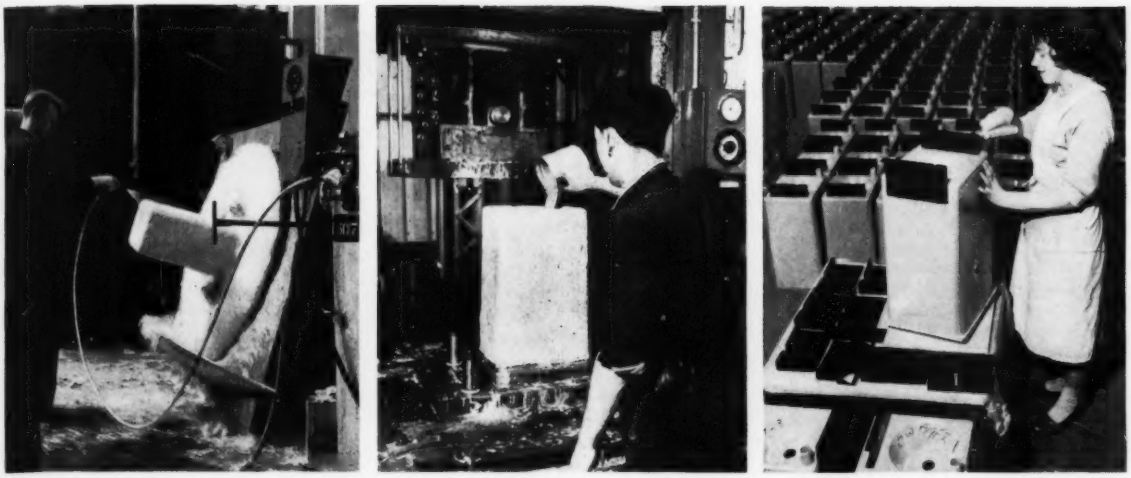
The benefits to be gained from the more highly alloyed case-hardening nickel steels, such as EN 33, EN 34, EN 36 and EN 39 include ease of heat-treatment, minimisation of processing distortion, and general reliability.

Please send for our publications entitled, 'The Mechanical Properties of Nickel Alloy Steels' and 'The Case Hardening of Nickel Alloy Steels'

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, SW1

TGA 21/2Z



Three stages in the production of the water container for the A.E.I.-Hotpoint Supermatic washing machine: (left) applying binder to the preform ; (centre) introduction of resin before the pressing and curing operation, and (right) attaching ancillary fittings, including two Ferobestos bushes.

Plastic Outpoints Metal

THE WATER CONTAINER for the spin dryer compartment of the new A.E.I.-Hotpoint Ltd. Supermatic washing machine is press moulded in Feroglas glass reinforced plastics, and is an excellent example of moulding in this material. It is produced from matched metal moulds in quantities which may well represent the highest production rate outside the U.S.A. for a single g.r.p. moulding. J. W. Roberts Ltd. are the manufacturers.

Glass reinforced plastics was chosen because it offered several advantages over production in metal. The deep draw required, and achieved, in this press moulding would have been extremely difficult to reproduce in metal. This will be appreciated from the dimensions, which are $14\frac{1}{8} \times 11\frac{3}{8} \times 21\frac{1}{4}$ in. deep—draw permitted 1 deg. 21 minutes—wall thickness 0.080 to 0.090 in. The container is stronger yet lighter in weight than a comparable item in metal due to the high strength to weight ratio of g.r.p., which has excellent chemical, weather and corrosion resistance and is therefore ideal for the production of water containers and similar products in contact with water. The material will withstand a great deal of rough treatment.

Dependent on the design and quantity, g.r.p. press mouldings are more economical to produce than metal components. In domestic appliances and similar equipment the use of g.r.p. reduces "drumming" and the transmission of noise usually associated with sheet steel.

THE AUGUST ISSUE

of Engineering Materials and Design will include the following main features:

Industrial Process Timers

Survey of timing units, as an aid to selection.

Air Cushion Vehicles

Design criteria in relation to performance over land and water.

Rectangular Hollow Sections

Designing with rectangular tubing.

Fatigue Strength of Aluminium Alloys

Comparison of BS L77 and DTD 5024 under combined and direct stresses.

Fluorine-containing Polymers

Recent developments of materials having high thermal stability.

Pipes and Pipelines

THE COMPREHENSIVE DISPLAY at the First International Pipes and Pipelines Exhibition revealed the considerable progress being achieved in this versatile industry. Indicative of modern trends is the development of plastics, significantly marked by the fact that many manufacturers of ferrous and non-ferrous pipes and fittings have been attracted to this field. Here the emphasis is on economy in labour costs, and corrosion resistance. An example is a 6-in. diameter pipe made of a glass fibre reinforced epoxy resin which, with suitable equipment, can be laid at the rate of 200 ft. per hour by three men. Chemical resistance of this pipe is very good up to 140 deg. C.

Pipe flexibility, essential in the aircraft and automobile industries, was prominently featured, notably the nylon-metallic braided hose for high working pressures in hydraulic, lubrication and fuel applications. Modern industrial air and water hose were on view, with small accessories which can reduce installation and repair costs to a fraction of that required by previous methods. Stainless steel figured extensively among the materials for pipes and couplings, for extreme temperatures and corrosive environments.

Pipe bending, cutting and threading machines showed evidence of continued progress, one of the most ambitious machines being for the manufacture of pipe from helically wound and welded steel strip. The demonstrations of transportable radiographical equipment, using the gamma ray technique for the detection of flaws in welds, were also of interest.

Thermal insulation and corrosion resistance being of paramount importance in this branch of industry, it follows that many of the exhibits were concerned with the solving of these problems. Ingenious machines for spraying the internal surfaces of pipes with the new epoxy coal tars were shown, also a powdered insulant which, when packed around the pipes, is said to provide highly efficient thermal insulation and complete protection from external corrosion. Other machine exhibits included trenching machines and side loaders. The success of this first exhibition should prove the precursor to many more.

U.S.S.R. Choice of British Goods

AS THE RESULT OF a request, to the chairman of the Praesidium of the All Union Chamber of Commerce of the U.S.S.R., to indicate the type of engineering equipment and capital goods which would be of the greatest interest to the Russian visitors to the British Trade Fair in Moscow, in 1961, a comprehensive list has now been received by Industrial and Trade Fairs Ltd., the organisers. This list is probably one of the most important documents relating to Russian opinion of British goods yet received in this country, and industrialists would do well to consider its contents seriously.

TECALEMIT *Nylon* TUBING ACHIEVES **WORLD** SUPREMACY

Tecalemit, pioneers of extruded nylon tubing, owe their present supremacy in this sphere to the most exacting research, testing and development in co-operation with the producers of the raw material. Tecalemit have now achieved marvellous limits of precision in extruded nylon tubing—limits unequalled and indeed unthought of previously—an exclusive technical triumph.

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T695

The illustration shows (left to right): Mr. B. Pidgeon (export manager, R. H. Windsor Ltd.) and Mr. J. W. B. Peel (I.C.I. East European Department), with Mr. Khruschev (centre).

Solderability of Coatings

AN INVESTIGATION at the Tin Research Institute's laboratories throws light on the variability in soldering quality of metal surfaces, especially of tags used in radio, television and electronic equipment. Such tags are usually of brass electroplated with another metal to prevent tarnishing and corrosion. Some thousands of a commonly used type of brass tag were procured for the investigation, and were electroplated with tin, zinc, cadmium, silver or other metals with special precautions intended to ensure dependable coating thickness.

It was found that coatings of tin or alloys of tin with lead, zinc or cadmium generally give excellent initial solderability and retention of solderability when not less than 0.0003 in. thick. Hot-dipped tin coatings are pre-eminent for soldering quality, and if solderability is the sole criterion, tin alloy coatings have no advantage over pure tin. There is no decrease in solderability of coatings on steel when applied correctly and stored under non-corrosive conditions. However, with a brass basis, deterioration may occur in the solderability of electrolytic coatings after storage due to zinc diffusion and consequent action of atmospheric moisture when storage conditions are unsuitable. A 0.0001 in. thick copper undercoat beneath electro-plated tin or alloy coating, or a 0.0001 in. thick nickel layer (under hot-dipped tin coatings), alleviates this difficulty. In the latter case, contamination of the dipping bath by zinc is also prevented.

A copper basis leads to decrease in solderability due to loss of coating as tin-copper intermetallic compound, but this loss is only serious for coating thicknesses less than 0.0003 in. An undercoat of 0.0001 in. nickel gives enhanced initial solderability and no deterioration in storage of adequately thick coatings, but the final coating should be applied without any delay. A 0.0001 in. copper undercoat generally enhances initial solderability of steel and brass, but decrease in solderability of thin coatings occurs when plating direct on a copper basis. Flow-melted tin coatings show slightly superior storage properties compared with as-plated coatings of a similar thickness, when both are on copper.

Storage should be at ambient, or preferably at 25 deg. C., to prevent condensation and it should be for the minimum possible period. This applies particularly to brass and copper work. Humidity and atmospheric contamination should be kept low, perhaps by storing the coated work in inert containers containing a desiccant.

British Plastics in Russia

THE I.C.I. PLASTICS DIVISION exhibition at the Polytechnical Museum, in Moscow, was visited on June 2 by Mr. Khruschev, accompanied by members of the Praesidium Central Committee. Mr. Khruschev said that he welcomed this kind of informative exhibition and wished it every success.

Tungsten's Future

IN THE PAST, much of the knowledge of tungsten has been associated with the production of lamp filaments and narrow strip. But today, because of the strong interest in the high-melting metals, technical advances in tungsten metallurgy are likely to proceed at a much higher rate than heretofore. The Battelle Institute have summarised its potentialities in the various applications in it tungsten is likely to be of interest in U.S. technology.

Increasing demand for alloys with service ceiling up to 1370 deg. C., and even higher, is resulting in the use of higher tungsten additions to cobalt-base alloys and further development of tungsten-base alloys. Some potentially important tungsten-rich alloys contain 2 to 10 per cent alloying additions. The molybdenum-tungsten alloying system is currently of great interest and will encourage greatly increased use of tungsten. Development of dispersion-hardened alloys as well as other tungsten-rich alloys will call for more of the metal. It is believed that use of tungsten in these alloys will increase to several times the present rate in the next five years.

The U.S. Government is strongly interested in wide tungsten sheet for high-temperature structural applications. If present interest and technical success continues, this type of usage may at least double in the next five years. Since it is now possible to forge tungsten shapes, some growth in use of the metal in this form is also expected.

Promising developments in slip casting of tungsten powders, vapour-phase plating and arc-spraying of the metal may be of moderate importance in increasing the use of tungsten. At the same time, no great increases are expected in the following uses of the metal: gamma-ray shielding; cemented or sintered carbides; cast tungsten carbides, and tungsten chemicals.

In conclusion, the Battelle metallurgists point out that the current strong interest in, and the intense research being done on, high-melting metals make it appear that technical advances in this field will proceed at an unusually high rate. Work to obtain wide sheet and castings, use as an alloy base, and as a major alloying addition to other refractory metals is opening new fields of application that were not possible in the past. All of these developments should lead to a major acceleration in the use of the metal in the years ahead.

Conference on Metal Finishing

AMONG THE PAPERS presented at the recent conference of the Institute of Metal Finishing, one on "The Use of Vinyl Resins in Appliance Finishes" was of particular interest in view of the good resistance of vinyl resins to heat and chemicals. This paper, by P. R. Day (I.C.I. Ltd., Paints Division), dealt with the properties of vinyl polymers and the types of finish which it is possible to achieve. Comparison was drawn between acrylic systems and those based on epoxy semi-dry, and non-drying, alkyds.

The unique characteristics of aluminium paint arise from the pigment used and the properties and production of this base were discussed in a paper by Gardam and Brace (Aluminium Laboratories Ltd.).

Processes for producing chromate and phosphate conversion coatings are well known, and recent emphasis has been given to the application of these treatments to zinc and aluminium. The paper "Studies on the Surface Treatment of Aluminium and Zinc," by Freeman Triggel (Pyrene Co.), surveyed and compared the types of chemical treatment which may be applied to zinc and aluminium for productive purposes.

Plastic coating is of particular interest, and the paper entitled "An Assessment of Coated Steel Sheets and their Use in Industry," by Smith and Tapp (John Summers and Sons Ltd.), described the different kinds of sheets now available, the problems of production and the protection of raw edges.

Carbon Coated Steel

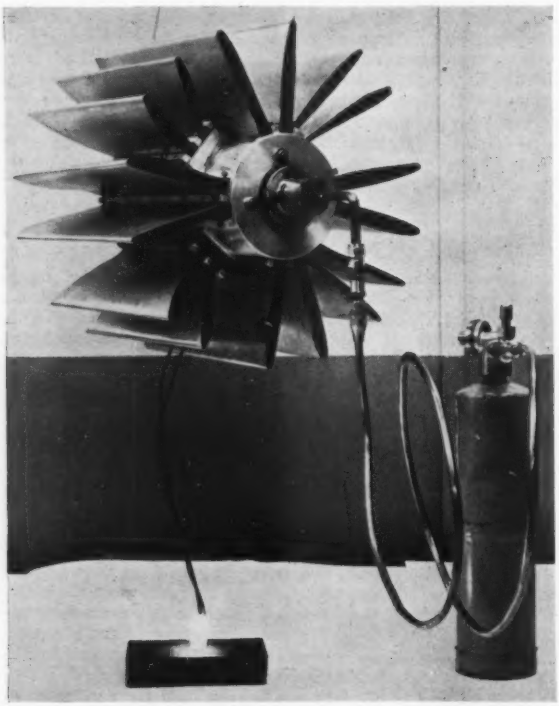
TEXAS INSTRUMENTS INCORPORATED recently announced the development of a process to coat carbon directly on to steel. Preliminary studies using experimental electron tube anode material made by the new process suggest that the material will have high emissivity and power dissipation with low gas content. The new material is said to be competitive with materials used at present.

Carbon-coated steel sample material is now under evaluation by electron tube manufacturers in actual tube applications. Findings from earlier tests conducted indicate that the new anode material has an emissivity comparable to gas carbonised nickel-clad steel with one-half to one-third the gas content. The material was fired and formed in tests without any carbon flaking—density is twice that of gas carbonised materials.

First reports from electron tube manufacturers indicate that, subject to the successful completion of tests, material coated by this process will find wide application in the industry. It is claimed that, with few exceptions, any metal may be carbon coated by the new process.

Thermoelectric Generator in Production

WHAT IS BELIEVED to be the first practicable thermoelectric generator to become commercially available in the U.S. has been demonstrated by the General Instrument Corp. The new generator employs semi-conductor thermocouple elements heated by a high efficiency propane burner, and the output is said to be 5 watts steadily and continuously for as long as the fuel supply lasts. Its light weight (10 lb.) and small size (12 in. high × 12 in. dia.) make it an attractive proposition as an unmanned power source in remote installations for operating communications or scientific equipment. Although the running cost is said to be small, of the order of £4 per year, the initial cost is extremely high, well over £1000. It is hoped that mass production will enable costs to be reduced to about one-tenth of this, but even so the cost per kW will still be more than 100 times that of present nuclear power stations. Therefore the new generator cannot be expected to meet applications for large amounts of power economically.



A thermoelectric generator developed by General Instrument Corp. converts the heat of burning propane gas into electricity. It is shown here supplying power to a small lamp.

Surface Control

BOUNDARY LAYER CONTROL has been studied for many years by aerodynamicists, and it is now possible to evolve a system giving a substantial reduction in drag. Not surprisingly a similar phenomenon exists with submerged bodies, as for example the submarine or underwater missile, and recently studies have been made on the surface texture of the skin of a porpoise, which by a form of boundary layer control can achieve a high performance under water.

One method of obtaining the necessary control of the layer of fluid adjacent to the body is by using porous skin and creating a pressure differential across it; this can have the effect of keeping the fluid close to the skin in a laminar or non-turbulent flow. The major difficulty is to provide a skin material that will display the necessary strength characteristics and at the same time have a controllable porosity. An answer to this has been provided by the use of sintered wire mesh in which a weave is made from very fine wire, several layers being laminated so that the wire of an adjacent lamination is positioned over the pore of the next. By rolling and sintering, each wire is bonded to its neighbour at every point where the wires cross. The resulting material can therefore be controlled accurately in thickness and porosity. Almost any metal can be treated in this way providing it is possible to draw the wire to a fine enough gauge, which is in the order of 0.0008 in. dia. and thicker. A further advantage, due to the locking of adjacent wires, is that the porosity will not vary after forming the material to different shapes. The strength, too, can be of a very high order, being imparted to the wire in the process of drawing to the very small diameters.

Another use for this material is not unrelated to aircraft, and is as a medium for increasing operating temperatures of turbine blades and skins of aircraft. In this instance the porous material is used as a sweat control where a cooling fluid is exuded through the skin to conduct away the heat. For the gas turbine application, a blade of the correct profile and of adequate strength was made up and slipped over a steel skeleton blade into which was led a bleed from an early stage of compression. The heat transfer which was possible led to a considerable increase in operating temperature and a gain in performance and efficiency. A blade of this type was recently shown at an exhibition by the Poroloy division of the Vokes Group.

A further use for this versatile material is as a carrier or matrix for silver bearing metal used on high-speed rocket sledges. For the high velocities and heat generated, silver has been found to be a suitable material for the runners. It is impregnated into the wire mesh, which wears away with the silver without causing scoring or appreciably increasing the friction.

FOR FURTHER INFORMATION:—

National Bureau of Standards (O.T.1), U.S. Dept. of Commerce, Washington 25, D.C.
W. S. Atkins & Partners, 158 Victoria Street, London, S.W.1.
Henry Balfour and Co. Ltd., Leven, Fife, Scotland.
Wakefield-Dick Industrial Oils, Castrol House, Marylebone Road, London, N.W.1.
J. W. Roberts Ltd., Chorley New Road, Horwich, Bolton, Lancs.
Pipes and Pipelines, 97 Old Brompton Road, South Kensington, London, S.W.7.
Industrial and Trade Fairs Ltd., Drury House, Russell St., London, W.C.2.
Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex.
Imperial Chemical Industries Ltd., Millbank, London, S.W.1.
Battelle Institute Ltd., 24 Ryder Street, St. James's, London, S.W.1.
Institute of Metal Finishing, 32 Gt. Ormond Street, London, W.C.1.
Texas Instruments Inc., 34 Forest Street, Attleboro, Mass.
General Instrument Corp., Newark, N.J.
Vokes Ltd., Henley Park, Guildford, Surrey.

Crane Braking—Old and New

We have been asked to point out that the new crane brake shown on page 388 of our July Issue is to be introduced by De Bergue Machine Tools Ltd. It is only the friction materials which are the concern of Ferodo Ltd.

Stronger Parts from Work-hardened Sheet Metal

This article, by H. A. Jahnle of the Budd Co., published in our May Issue, originally appeared in *Product Engineering* on October 26, 1959, page 76.

FOURTH R PHILOSOPHY

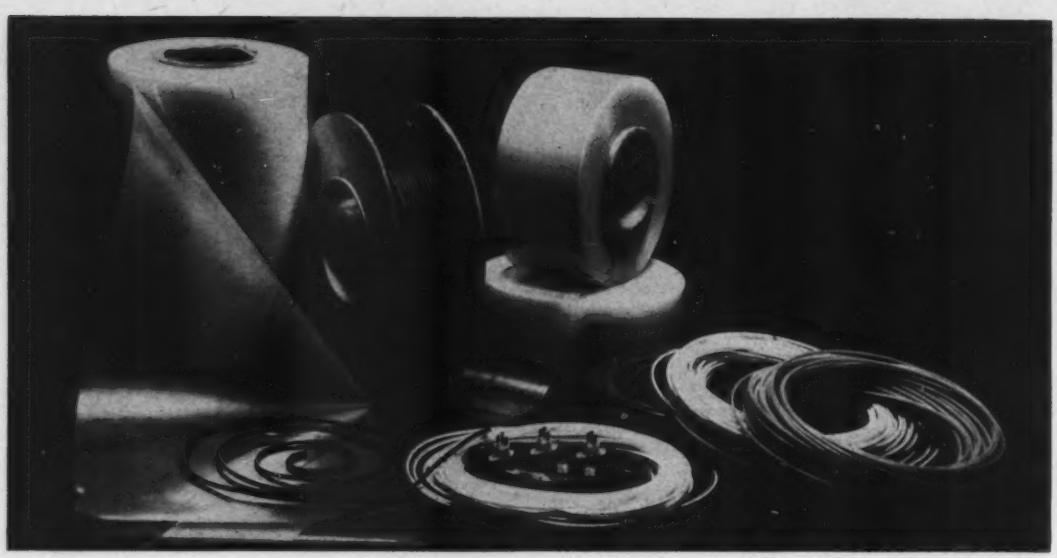
AT the British Electrical Power Convention, 1960, the Hon. H. G. Nelson in his paper, "The New Horizon—Electrical Manufacture", said: "One of the particular qualities for which the electrical manufacturer is searching in all materials and devices is reliability. The nature of our products is such that reliability is often more important relatively than cost or efficiency." This statement reflects a present-day emphasis on reliability that is to be found in nearly all branches of engineering all over the world. In fact, the word "reliability" is found regularly not only in technical papers but in publicity literature and annual reports of companies. In the U.S. it has been called the "fourth R", although we think that classing it alongside the basic elements of education is carrying the emphasis a little too far!

Reliability is such an obvious requirement in any manufactured product or material that one is tempted to question the need for all this fuss, but undoubtedly a problem has been created by the rapid development of new materials and techniques. The exploitation of many newfangled devices is one of the designer's greatest worries, mainly on account of reliability. General exhortations to design for reliability are becoming a little monotonous, and unless accompanied by constructive hints on how to do it they are meaningless. One of the main difficulties in trying to get down to constructive detail is that the word "reliability" has a completely different meaning in different branches of engineering. To the Post Office engineer designing repeaters for the transatlantic telephone cable it means freedom from any failure for a period of 50 years; to a guided-missile man it means 100 per cent working of several thousand components for a few minutes, and to the automobile engineer one gets the impression that reliability means the providing of an efficient service for replacement parts! Actually this last suggestion is not so frivolous as it may first appear, because the link between design and maintenance should be a very strong one. A designer of special-purpose machinery for the manufacture of lamps recently told us that the cost of a stoppage in production of a mass-produced article like a lamp is so great that the main consideration is the speed with which faults can be recognised and rectified. Therefore, he advocated the design of machinery on a purely mechanical basis with the absolute minimum of electrical, hydraulic or pneumatic features. The object in this case is to make sure that the equipment gives a relatively trouble-free life, but if a breakdown does occur it can be quickly diagnosed by an ordinary mechanic, whereas complex modern gadgetry needs a specialist.

Possibly there is some merit in the view that designing for reliability is just another fashionable catch phrase. Not many years ago automation was considered by many to be an unnecessary word to describe the logical development of mechanisation and more recently the word ergonomics has been frowned upon by many of the older engineers, who claim to have embodied all the principles without having invented a new piece of jargon to justify it.

The Press are often blamed for plugging technical jargon, in spite of the fact that it is often the scientists and technologists who seem to delight in making simple ideas sound complicated, while the Press are constantly struggling to simplify the abstruse. With the subject of reliability, however, there is nothing particularly new or objectionable so long as it is treated as a vital part of good design and not considered as an end in itself. Although we would hesitate to give a definition of good design—many more qualified than we are have failed to do this with universal agreement—the proper balance between cost, function, ergonomics and the many other factors involved, including reliability, must be a large part of it.

The Editor



IRRADIATED POLYTHENE

Use of polythene offers a solution to many problems of design—irradiation further extends its potentialities

by T. BAIN, B.Sc., A.R.I.C., and W. H. T. DAVISON, M.A. (Cantab.), F.R.I.C. *

DURING and since the war polythene has proved itself to be one of the most versatile and useful plastic materials in existence. It can be extruded, moulded and cast; the surface finish obtainable is excellent; the techniques employed in its fabrication are not at all difficult, and the finished products possess an imposing line-up of properties, both physical and electrical. Indeed, the rapid development of radar was due in no small measure to the unique electrical characteristics of this material, while today its applications range from the specialised to the commonplace.

For many purposes polythene in its normal form as fabricated is perfectly satisfactory and no modification is either necessary or desirable, but in certain conditions it is unable to stand up to its environment and may fail when subjected to elevated temperatures or to attack by some chemicals. In such cases irradiation of the polythene has frequently been found to give a material of considerably wider application and longer useful life. Irradiated polythene has been available commercially in the U.S.A. for about four years and in the U.K. for three. At present the most important outlets are as cable and film, while several users of polythene, particularly in the electrical field, have found that their own specific products are more easily made or more satisfactory in service if their polythene components are irradiated before assembly.

A certain amount of misunderstanding exists regarding the irradiation process, and indeed about industrially-applied radiation generally. The subject is bound up, in the minds of many people, with the question of biological hazard associated with the handling of radioactive materials, and potential users frequently seek assurance that irradiated items exhibit no "residual radioactivity". Although the word "radiation" strictly applies to a very wide spectrum of electromagnetic waves, ranging from long-wave radio through visible light to X-rays, it is used here in the special sense of high energy, i.e., ionising, radiation and includes high-velocity primary particles such as neutrons and electrons. Industrially speaking, radiation sources may be considered under two arbitrary headings, namely, radioactive isotopes and electrical machines. The former may consist of spent atomic-reactor fuel elements, fission products separated during their reprocessing, or neutron-bombarded elements specifically treated in the pile for subsequent use as radiation sources. The commonest example of this last type is Co 60, which is being widely used at present in the radiation field.

Irradiation by Electrical Machine

Irradiated items such as those mentioned above—film, cable, etc.—are most usually produced using electrical machines which give a stream of high-velocity electrons. One of the commonest of these electron accelerators is the Van de Graaff electron generator (see Fig. 1), consisting essentially of a charging belt, a high-voltage terminal and an evacuated accelerating tube. Electrons are sprayed on to the belt from a transformer/rectifier power-pack unit and carried by it to be deposited at the high-voltage terminal, which is thereby charged to a potential of several million volts. One end of the accelerating tube is situated within the influence of this terminal; electrons from a filament at this end of the tube are accelerated as they pass to the other end, which is at ground potential; they then pass through a thin aluminium window into the atmosphere. The electron beam may be scanned after the fashion of the beam in a

* *The authors are attached to Tube Investments Research Laboratories, Hinton, Cambridge.*

T.V. tube, so that they emerge from the tube as a thin "fish-tail", through which the items to be irradiated are made to pass, for example, on a conveyor belt. Most industrial machines used for the radiation-modification of, for example, plastics operate at from one to four million volts, and the electrons have insufficient energy to penetrate the nuclei of any of the atoms comprising the bombarded material. Without such penetration, radioactivity cannot be induced, and the materials treated by these machines are quite safe to handle even immediately after irradiation.

Simply stated, the mechanism of the irradiation process may be considered as follows. Each polythene molecule consists of long chains of carbon atoms to which are attached one or two hydrogen atoms. The effect of high-energy radiation upon this structure is to abstract one or more hydrogen atoms, leaving the molecule chemically unsatisfied. Two such unsatisfied molecules may then join together to form one larger unit, to which the same sequence of events may occur. In this way a mass of polythene which formerly consisted of a very large number of molecules each containing, say 2,000 carbon atoms, comprises, after irradiation, a much smaller number of larger molecules, entwined through each other and forming a network throughout the article.

The number of such "cross-links" introduced into the polythene depends upon the amount of radiation to which it is subjected, the usual dose for commercial applications being from one to fifty million rads. (A rad is equivalent to an energy deposition of 100 ergs per gm. within the material. The normal unit for massive doses is the megarad, i.e., 10^6 rads). At the lower end of this scale polythene shows little change, while doses of the order of hundreds of megarads transform it to a transparent, brittle, "cheesy" material of very inferior physical properties. At doses of ten to fifty megarads there is little obvious change in appearance at room temperature, but due to the cross-linked structure the molecules no longer have so much freedom of movement, and on raising the temperature to its crystalline melting point the polythene becomes rubber-like instead of changing to a viscous fluid as when unirradiated. For this reason irradiated polythene cannot readily be processed by normal means. This state of affairs is very analogous to that obtaining in rubber technology, where the unvulcanised rubber compound can be extruded, moulded, expanded, etc., but, once vulcanised, exhibits the characteristics of an elastic rather than a plastic solid.

Since the effect of introducing cross-links is similar in both the lower density polythenes and the more recent high density grades, the irradiation process is equally applicable in both cases. High density polythenes, irradiated or not, may be used at temperatures above those tolerated by low density grades, and may, for instance, be sterilised in boiling water; one of the advantages of using the irradiated product, however, lies in the absence of the normal relatively sharp melting point should the transition temperature (approximately 130 deg. C.) be exceeded.

As already stated, there is at room temperature little visual evidence of irradiation, but for certain applications great improvement in properties is achieved (see Table 1). Ordinarily, polythene has poor resistance to stress-cracking when in contact with some liquids, such as organic solvents, solutions of detergents, etc., and even those which do not chemically attack it can cause deep cracks, these leading to complete component failure in a surprisingly short time. Irradiation makes polythene very much less susceptible to attack by such agents, and strained moulded parts have been immersed for prolonged periods without suffering breakdown. In addition, it strongly inhibits thermal embrittlement (i.e., the tendency of certain types of polythene to become brittle after prolonged exposure to temperatures around 70 deg. C.).

The accompanying graph (Fig. 2) shows the useful tensile strength retained by irradiated polythene at 150 deg. C. at various levels of irradiation, and also the effect of reinforcement of the material by the addition of silica and carbon black. These have somewhat the same effect as when incorporated in rubber. Such reinforcement is sometimes necessary when moderate loads have to be carried by polythene members at elevated temperatures.

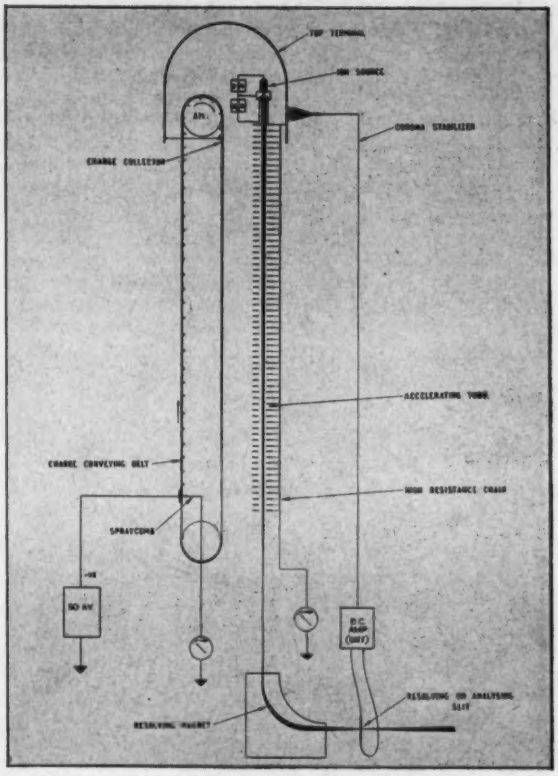


Fig. 1. Schematic diagram of a 6-MeV. pressurised Van de Graaff accelerator.

Available Processing Methods

Were it not for the fact that fabrication must precede irradiation, the final form in which the polythene is to be used would be of no interest to those concerned with the design and operation of suitable handling and irradiation equipment. This, however, is not so, and satisfactory irradiation must always take into account the dimensional and other factors of the product to be treated. In this field expertise cannot readily be stated in text-book terms, but is compounded largely of experience in the handling of items of widely-varying shape, size and composition.

The methods available for processing polythene are many and varied, but perhaps the two main production operations are moulding and extrusion, the latter being divided as regards the finer details of technique into film extrusion, requiring a very specialised approach, and rod, tube and cable-covering extrusion where tolerances are normally somewhat wider. By the same token irradiated polythene is most commonly used in the form of film (usually from 0·002 to 0·010 in. thick), electrical wire and cable insulation, and mouldings, although for special applications irradiated polythene components have been developed using centrifugal casting, vacuum forming, pre- and post-irradiation expansion and a number of other techniques.

Use of Polythene Film

Perhaps the electrical field is the most obvious in which the properties of irradiated polythene film can be exploited. It possesses high dielectric strength, its volume resistivity is of the order of 10^{16} ohm-cm., and its power factor is among the lowest of any dielectric, about 5×10^{-4} at frequencies up to 10^9 cycles per second. Room temperature tensile strength for low-density polythene is about 1,900 p.s.i., and 3,000 p.s.i. for high density material. At about 115 deg. C., at which unirradiated film would be fluid, a tensile strength of from 200 to 400 p.s.i. is retained, helping to safeguard electrical apparatus against the results of overload. Moisture is practically without effect, and the film is extremely resistant to chemical attack.

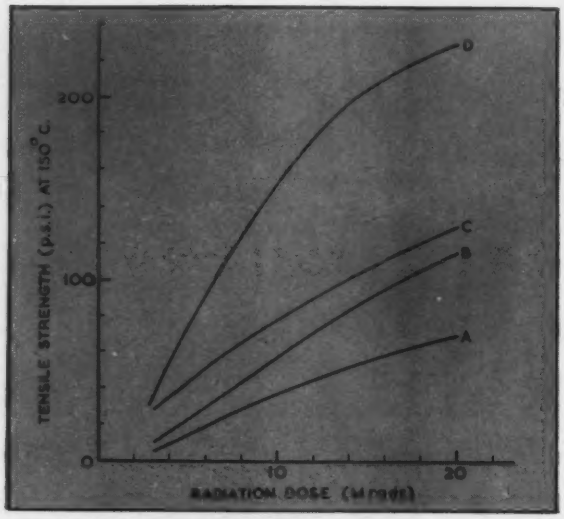


Fig. 2. High-temperature tensile strength of a number of irradiated polythene formulations.

KEY: A—Alkathene 2 (I.C.I. Ltd.). B—Rigidex 15 (British Resin Products Ltd.). C—Alkathene 2, 100 parts by wt.; Aerosil (Bush, Beach & Segner Bayley Ltd.), 20 parts by wt. D—Alkathene 2, 100 parts by wt.; Philblack 0 (Philblack Ltd.), 33 parts by wt.; Nonox C.I. (I.C.I. Ltd.), 0·4 parts by wt.

TABLE I.

	Tensile strength (p.s.i.)	Modulus at 100% elongation (p.s.i.)	Elongation at break (%)
Room temperature	1,900	1,500	550
100°C.	500	350	500
125°C.	100	40	400
150°C.	55	25	300
Electrical	Dielectric constant (20°C., 50 to 10^{10} c.p.s.)	2·3	
	Power factor (50 to 10^{10} c.p.s.)	0·0005	
	Volume resistivity (25°C.)	$>10^{16}$ ohm.-cm.	
	Dielectric strength (20°C., 50 c.p.s.)	1,500 volts per mil.	
Non-electrical	Thermal conductivity (20°C.)	2·5 B.t.u. in./ft.² hr. °F.	
	Specific heat (20°C.)	0.55	
	Coefficient of linear expansion	0·025% per °C.	
	Water permeability (20°C., 100% R.H.)	4 gm./sq. metre/24 hr./mil.	
	Water absorption (20°C.)	Negligible; less than 0·05%.	

The physical properties shown are for Alkathene 2 irradiated to 15 Mrads; the higher-density varieties show figures of tensile strength, modulus and elongation at break up to double these values, depending upon the method of manufacture.

Prestressed irradiated film will shrink when heated above the transition point, and at this temperature is self-adherent. It is therefore an effective means of applying insulation to motor coils, transformers, resistances, etc. The component is merely wrapped with the tape and subsequently raised to about 140 deg. C. for a few seconds to shrink the film. Taping and further sealing may be carried out subsequently, according to normal practice. This heat-shrinking property has also been successfully employed in the encapsulation of small electrical components and circuit junctions in the building of electronic units in which ingress of dust and moisture must be avoided.

In many service applications where conditions of operation are variable and severe, irradiated polythene film is an ideal material for use as a condenser dielectric on account of its low power-factor and non-melting properties. It can withstand prolonged periods of service while in the "elastic" condition without undue loss of properties, particularly if oxygen access is prevented; as a further safeguard the polythene may be compounded with antioxidants where longer-term operation at elevated temperatures is required.

In addition to its electrical applications, irradiated polythene film is a useful and easily-handled material for the packaging and protection of many products. Ordinary polythene film is used at present for the packing and transporting of foodstuffs of all descriptions, fruit and vegetables, confectionery, meat, pastry, etc., in addition to pharmaceutical products, stationery and small miscellaneous items such as nuts and screws and model parts. Trials with irradiated film have confirmed expectations that it would retain the original good properties while offering advantages of its own.

For the protection against dirt and corrosion of items of machinery or of metal components during transport and storage, the irradiated film is an obvious choice, since it is tough and easy to seal. In addition, where the application of heat is permissible, the article may be cocooned by wrapping (or enclosed in a pre-distended envelope), and subsequently heated to 140 deg. C.; a tightly-stretched sheath will result, giving increased sales-appeal to such items as small tools, cycle-spares and the like (see Fig. 3).

A further use to which this film lends itself is the wrapping of metal underground pipes subject to corrosion by the soil, and of certain types of underground electrical junctions where exposed metal braiding or sheathing has to be protected from soil attack and moisture. In these applications the stress-cracking resistance of the irradiated polythene is employed to advantage.

Extruded Forms

During the past few years irradiated polythene has emerged as a most satisfactory material for use as wire and cable insulation. Among those of its properties exploited in this application may be mentioned toughness, chemical stability, stress-cracking resistance, non-flow high-temperature characteristics, low power factor, ease of colour-coding and absence of run-back during soldering. As in the manufacture of other products incorporating irradiated polythene, the material is fabricated in the unirradiated condition. Extrusion of the polymer over the wire is carried out without any difference in detail apart from the incorporation in certain cases of agents designed to improve its high-temperature performance. The finished wire is then irradiated on a handling rig specifically designed for it. This "made to measure" treatment is necessary, since efficient handling and irradiation are dependent on several factors, including actual wire-strand diameter, radial thickness of polythene, composition and configuration of the conduction core, and the presence or absence of such "extra" items as metal braiding or non-polythene sheathing.

Where cable irradiation is carried out with a beam of high-energy electrons (the only commercially-operated method)

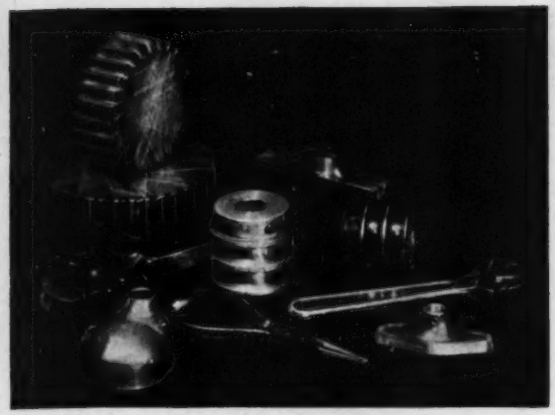


Fig. 3. Protection of metal parts by irradiated polythene film.

several variables have to be controlled, including beam current and accelerating voltage, and for economic processing the efficiency of electron-beam utilisation must be as high as practicable. This is achieved by presenting the wire to the machine in an array suited to the above cable variables, and by matching irradiation conditions with the characteristics of the beam. Since the useful penetration of high-energy electrons into polythene is about ¼ in. per million volts, the range of cable sizes which can be processed on, for instance, a two-million-volt machine, is quite considerable. In addition, multiple-core cable may be built up from separate already-irradiated cores and the final assembly then irradiated to cross-link the outer sheathing.

Wire insulated with irradiated polythene can be used at ambient temperatures of 120 deg. C., or where they may rise to 150 deg. C. or more, and can withstand much higher temperatures for short periods or in the absence of oxygen. (In an actual test, wire covered with irradiated polythene has been found perfectly serviceable and practically unchanged after immersion in molten solder for several days at a temperature of about 300 deg. C.; under the same test unirradiated polythene and p.v.c. failed in less than one minute.) In circuitry the absence of melting facilitates soldering operations and ensures a neat finished appearance. In this connection it may be mentioned that irradiated polythene sleeving possesses the same advantages, being more heat-resistant than p.v.c. and more flexible than impregnated fabric sleevings.

The use of polythene tubing in the chemical industry has now become standard practice where certain types of corrosive or solvent liquids are handled. Its relative inertness and resistance to chemical attack make it the ideal and sometimes the only practicable material to use. Some agents may, however, cause cracking of the tubing, particularly at temperatures around 70 deg. C. The irradiation of polythene tubing when it is to be used in such environments greatly offsets this weakness, with consequent reduction of maintenance and replacement costs. Auxiliary fluid-handling equipment such as valve-diaphragms, nozzles, filter-plates and pump components are equally improved by radiation in their resistance to heat and crazing.

Components and Containers

Apart from film, equipment-wire, sleeving and those products irradiated by the manufacturers before being marketed, a very large variety of electrical components, small accessories, domestic articles, extrusions, pharmaceutical containers and miscellaneous mouldings are submitted by the actual users for irradiation, in order to improve the efficiency of the particular item or to prolong its useful life. Some electronics firms, for instance, find that rapid and efficient soldering to multi-point polythene plugs and sockets calls for very considerable skill, and that a small error of judgment results in melting of the polythene, ruining the components. When irradiated components are used this danger is virtually removed, since no permanent flow of the plastic occurs. Similar benefits have been recognised in using irradiated polythene for the end sections of co-axial and radio-frequency cable where small permanent displacements during soldering are expensive and unnecessary sources of trouble.

Polythene containers for some of the more active stress-cracking agents used in cosmetic and pharmaceutical preparations can be protected by irradiation against splitting in use. Wash-bottles and laboratory tubing last longer, and innumerable small polythene articles such as grommets, bushes, "O"-rings, washers and extruded seals stand up to hotter conditions and more rigorous service when irradiated.

Polythene has become such a ubiquitous material, and is the answer to so many problems of design and performance, that a comprehensive survey of the applications in which its unique properties are utilised is quite impossible. Since for many purposes irradiation further extends its usefulness, designers and other potential users have shown great interest in this modified form of an already-proved plastic in their own specific fields. This, in turn, has stimulated research into the development of specialised formulations for improved resistance to oxidative breakdown, and into the question of reinforcement to provide materials of greater high-temperature modulus. Indeed, as in the exploitation of any relatively new product, such collaboration between supplier and user is the best means of ensuring the most profitable utilisation of this versatile material.

The writers thank the chairman of Tube Investments for permission to publish this article.

L.P. GAS AS A POWER SOURCE

THE use of liquefied petroleum gas for supplying light and heat is well known, particularly to caravaners and boating enthusiasts, but as a source of power it is not so widely appreciated.

The neat installation of a rigid tank on the Hyster fork-lift truck shown on the Fred Myers Ltd. stand at the recent Mechanical Handling Exhibition contained sufficient l.p. gas for about 12 hours' running with a 12,000-lb. capacity lift truck to 30 hours' running with a 2,000-lb. capacity lift truck. The engines of these trucks are of the conventional internal combustion type, modified in cylinder head design to give optimum performance on a propane-butane mixture. The fuel passes from the tank as a liquid and is vaporised by a heat exchanger fitted before the carburetter, which with this fuel acts as a mixer for the gas and air.

The advantage of this form of power is a considerable reduction in the dangerous carbon monoxide exhaust fumes, which is of extreme importance when a truck of this nature is being used in a factory dealing with edibles or products of a similar nature. Compared with a petrol engine, where the CO content at idling is approximately 9-10 per cent, the l.p. gas system evolves only 0·1-0·6 per cent. At full load the difference is even more pronounced, the content of carbon monoxide being under 0·05 per cent.

Because the fuels have practically no gum or sulphur content, they burn evenly and cleanly when mixed with air, and offer an additional advantage in that the oil film is not washed from the walls or diluted as with petrol-fuelled engines. It is claimed that a major engine overhaul is not required for at least 100,000 running hours.

DESIGNING WITH RESIDUAL STRESSES

by G. M. SINCLAIR and JoDEAN MORROW *

TWO questions that designers of fatigue loaded parts must answer are (1) What is the fatigue limit? and (2) if the fatigue limit is exceeded, what is the fatigue life? These questions are further complicated when there are residual stresses involved. Recent rapid testing techniques have produced guiding data for at least part of the answers to these questions, when residual stresses are present.

Residual stresses should be looked upon as a portion of the stress that the surface material must resist. These stresses will not change in hard materials with moderately low residual stresses for amplitudes of alternating stresses near the fatigue limit. Even in a soft material, there will be little change when the member is stressed near the fatigue limit. Therefore, a reasonable estimate can be made of the fatigue limit of a member or part that has moderately low initial residual stresses by:

(a) Superimposing the initial surface residual stresses on the service stresses.
(b) Considering these stresses to remain unchanged during the fatigue loading.
(c) Treating the problem as any other in which a mean stress is present.

In solving a fatigue limit problem with a mean stress, it must be remembered that hard materials are more sensitive to mean stress than are soft materials. This characteristic is shown in Fig. 1.

When the initial residual stress is high or a load pattern is used that produces a stress greater than the yield strength of the material, the problem breaks down into two parts. The first is to determine what happens during the first stress cycle and the second is to repeat the procedure used for the low residual stress case.

The yielding on the first cycle may be quite large. This results in a new mean stress, σ_1, after the first cycle. From Fig. 2 it is seen that:

$$\sigma_1 = \sigma_y - \epsilon_a E = \sigma_y - \sigma_a$$

In this expression, ϵ_a is the amplitude of the alternating strain and $\sigma_a = \epsilon_a E$. With this new value of σ_1, the fatigue limit is calculated, assuming the new residual stress does not change during the fatigue loading.

Tests run on S.A.E. 4340† show good correlation of the mean stress at the end of the first cycle, as demonstrated in Fig. 3. In all cases, large yielding had occurred at the end of the first cycle. For the three hardness conditions of S.A.E. 4340, the following values of σ_y were used:

Soft (Rockwell C-29)	123,000 p.s.i.
Medium (Rockwell C-41) ...	172,000 p.s.i.
Hard (Rockwell C-50)	222,000 p.s.i.

These values are slightly less than the 0·2 per cent offset yield strength for the three hardness levels. This technique is not applicable for all metals. Some do not have the assumed "flat top" stress-strain curve, and the material may not unload linearly along a line parallel to the elastic modulus line.

FATIGUE LIFE—For stress above the fatigue limit, there is almost certain to be a change of the residual stresses. With present knowledge, it would be difficult to take this into account. One thing can be said, however. For sufficiently high alternating stresses or for soft materials, the surface material experiences completely reversed stressing after the first few cycles. Initial residual stresses, therefore, have very little effect. An estimate of the life can be made using a completely reversed (zero mean stress) S-N curve for the material.

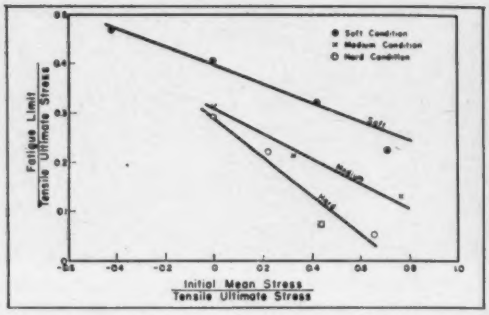


Fig. 1. Effect of initial mean stress on fatigue limit for three hardness values (29, 41 and 50 Rockwell C) of S.A.E. 4340.

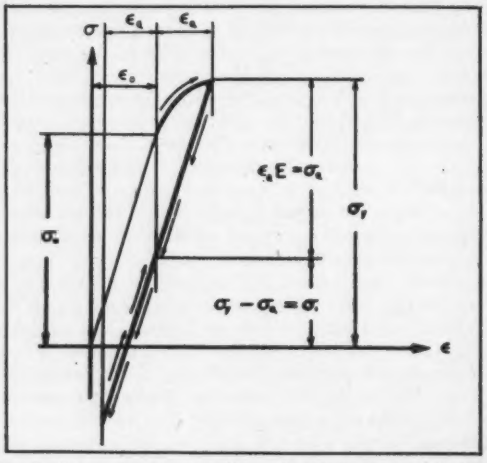


Fig. 2. Curve showing yield on the first cycle of fatigue loading producing a new mean stress for fatigue limit calculations.

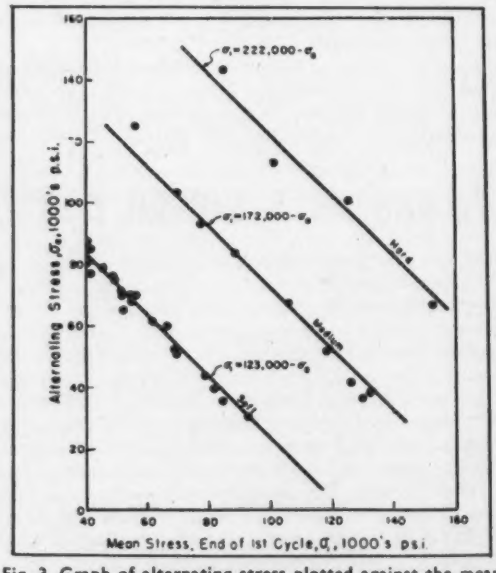

$\sigma_1 = 222{,}000 - \sigma_a$
$\sigma_1 = 172{,}000 - \sigma_a$
$\sigma_1 = 123{,}000 - \sigma_a$
Hard
Medium
Soft
Alternating Stress σ_a, 1000's p.s.i.
Mean Stress, End of 1st Cycle, σ_1, 1000's p.s.i.

Fig. 3. Graph of alternating stress plotted against the mean stress obtained from Fig. 2.

* The authors are attached to the University of Illinois, U.S.A.

† Open Hearth or Electric Furnace Alloy Steel (0·38-0·43 per cent C, 1·65-2·0 Ni + Mn, Cr and Mo).

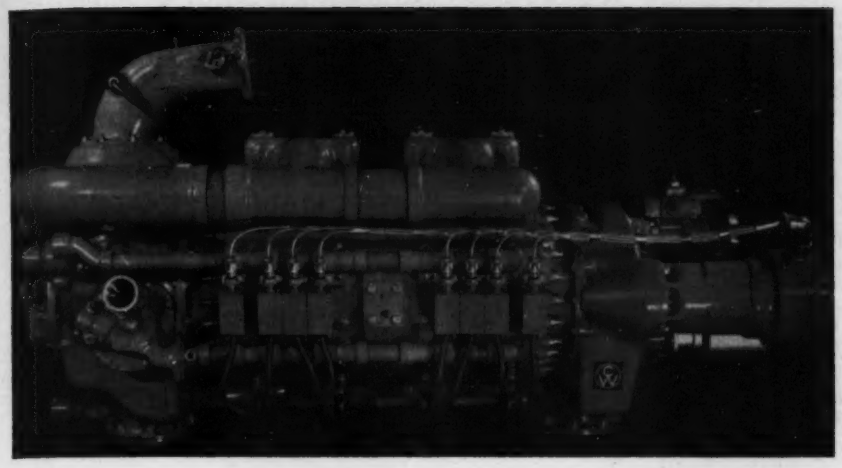


Fig. 1. Curtiss-Wright rotating combusion engine developed for aircraft applications.

PROPULSION—METHODS AND APPLICATIONS

In early civilisation, transport of cargo and personnel necessitated a vast amount of manpower; this survey discusses methods and applications used at present and visualised for the future

THE first major breakthrough for propulsion came with the steam engine, which, in its turn, introduced the motor car, train and ship, with odd attempts, some successful, to apply such power to aircraft. The next step was the electric motor, followed by the internal combustion engine deriving its power from petrol, oil or gas. The internal combustion engine with conventional piston, connecting rod and crankshaft has held its ground for many years, although numerous attempts have been made to design a rotating piston engine to avoid the disadvantages associated with reciprocating parts. A design of this type was recently announced by the Curtiss-Wright Corp., who, jointly with NSU Werke in West Germany, have developed the engine shown in Fig. 1. From the diagrams in Fig. 2 it will be seen that the expansion of the gases exerts a force which, due to the eccentricity of the rotor centre, causes it to rotate.

Two configurations were originally conceived, and both of these contained an outer rotor having a cavity within which an inner rotor was constrained to rotate. The two rotors have spaced but parallel axes, the inner surface of the outer rotor being an epitrochoid, while the outer surface of the inner rotor approximates to this envelope during rotation; the apices of the inner rotor are in contact with the epitrochoid at all times. The volume change with rotation is sinusoidal and a cut-out in the inner rotor provides the desired compression ratio and gas transfer passage. In one configuration both rotors rotate, while in the other the outer rotor is stationary, the inner rotor having a planetary motion about the axis of the outer rotor. The relative motion of the two rotors is, however, the same in both cases.

Fig. 4 compares the cycle of a single-unit rotating combustion engine with a single-cylinder four-stroke cycle reciprocating engine over crank angles covering four revolutions; the reciprocating engine has two power sequences, whereas the rotating combustion engine has four. The diagram shows also that each power sequence of the rotating combustion engine covers a wider crank angle than is the case with the reciprocating engine. Both intake and exhaust flow have shorter dwell periods for the rotating combustion engine, thus reducing intake and exhaust losses and providing a smooth operation. Typical power characteristics are shown in Fig. 3. An interesting multi-fuel engine of the conventional type is the Rootes two-stroke opposed-piston diesel engine, which, because of its compactness, offers wide versatility in installation. Each set of two pistons works in a common combustion chamber, the fuel being directly injected.

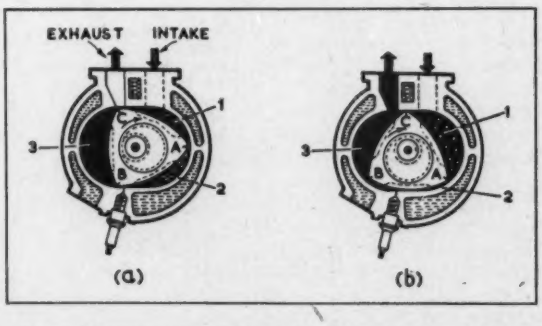


Fig. 2. Operating sequence of rotating combustion engine: (a) induction into 1, compression commencing in 2 and start of exhaust from 3; (b) inlet port closing to seal charge in 1, compressed charge in 2 ready for ignition and burnt gas exhausting from 3.

Marine Turbines

The increasing popularity of boating has stimulated the development of more powerful engines with improved economy, particularly in relation to the outboard type of power unit. A two-piston, single-cylinder opposed diesel outboard engine is already available, and a new design approach for petrol engines is shown by the Scott R.120, which is a four-cylinder radial two-stroke engine with direct fuel injection. Turbo-supercharging is employed, the output being 120 h.p. for a powerhead weight of 145 lb. In its outboard application, steering, power control, tilt and variable pitch propeller are actuated by electric remote controls, the v.p. propeller being the means of reversing the craft.

The Hydrocket propulsion system is, in effect, a water jet engine, the impeller being a hollow metal disc pierced at the periphery with oblique holes and fitted with internal guide vanes. By rotating at very high speeds, water is forced through the holes, creating a whirling spray which drives the craft forward. When under way, the impeller is clear of the water, thus reducing water drag and cavitation effects.

The Gill hydraulic jet propulsion unit is a well-proven system of propulsion for marine craft which dispenses with rudder and propeller and eliminates outside projections. The unit consists of an axial flow pump mounted within a short siphon-shaped passage open to the water at both ends. The motive force is produced by the pump drawing the water in at one end and expelling it at the other via a rotatable discharge deflector, which may be swung through 360 deg. to give directional and reverse thrust. A similar system for high-performance craft has been introduced by the Dowty[1] Group.

Hydrofoils are another form of marine development receiving attention, a recent design being the Russian concept.[2] Hydrofoil craft were designed and built by Saunders-Roe (Anglesey) Ltd. for the Canadian Government in about 1957, while a recent announcement that the U.S. navy has placed orders for this type of craft is not without interest. In these the propulsive effect can be either by propeller at the lower end of a vertical stalk, or by turbo-jet.

The Magnus effect, which is the generation of lateral thrust by a rotating cylinder, is well known, and the most spectacular application of this phenomenon was applied to the ship *Barbara*, which twice crossed the Atlantic in 1927; little has been heard of ship or system since. Although an ungainly arrangement, it is possible that advantage may be taken of this effect in other applications.

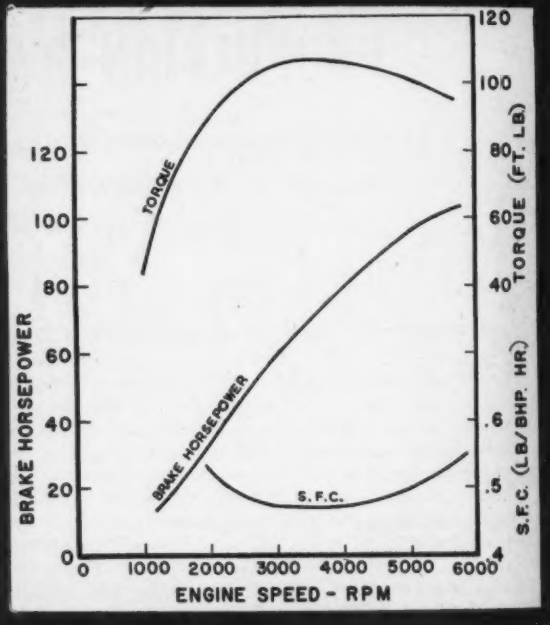
Gas Turbines

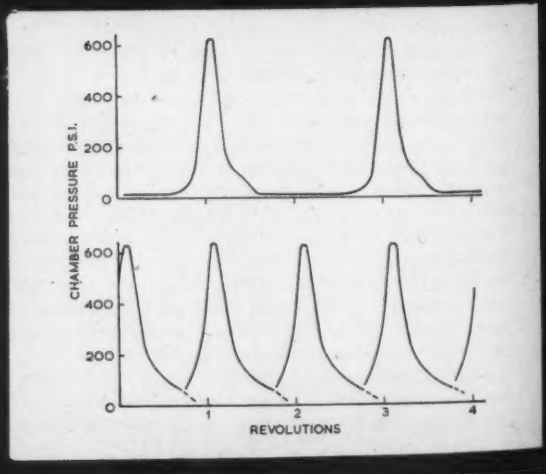
The gas turbine was a logical development from both steam turbine and i.c. engine, and brought the need for hand-in-hand development of materials with design sharply into focus. Primarily developed for aircraft, the gas turbine has been used with success in rail propulsion, ships and, to a very limited extent, motor cars. Its biggest potential outside transport is probably portable power units for pumping and electric power generation.[3]

Significant developments in the car industry suggest that the turbine engine will become a production possibility in the not too distant future, the present main obstacles being the high cost associated with precision manufacture, the relatively short life of many parts in order to achieve running reliability, and the high fuel consumption. The introduction of the Ford type 704[4] supercharged gas turbine engine suggests that these problems have largely been solved, this particular engine weighing only 650 lb. for an output of 300 h.p., with a fuel consumption comparable with a diesel of equal power, and superior under most conditions compared with a petrol engine.

The Allison GT-305 Whirlfire 225-h.p. gas turbine engine is basically a vehicular propulsion engine, and has been fitted to the General Motors Firebird II and III car. The practical application of a regenerative cycle has resulted in the economical operation of this engine with lower exhaust temperature and noise level.

The introduction of a small gasifier which dispenses with the compressor stage of a turbine unit offers the possibilities of this form of power being used in tractors and commercial vehicles. The exhaust gas turbine may also provide the means of propulsion for medium-size vessels, the S.S. *Moray* being an example where three gasifiers are used to feed a single turbine unit. The power output in service is 2,500 shaft horsepower, each gasifier providing about 1,000 equivalent s.h.p., thereby creating a reserve. This type of power unit is more compact than the conventional steam plant and can show a saving in weight which may be utilised as cargo space, offsetting the fuel consumption, which at 0·42 lb./s.h.p./hr. is slightly higher than a comparable diesel engine.

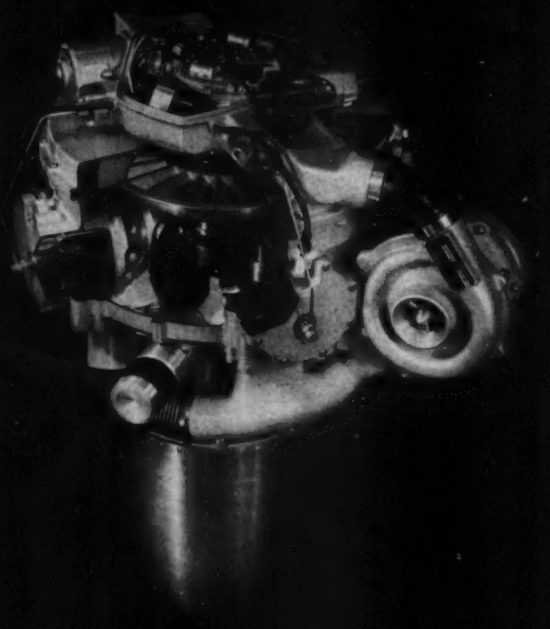


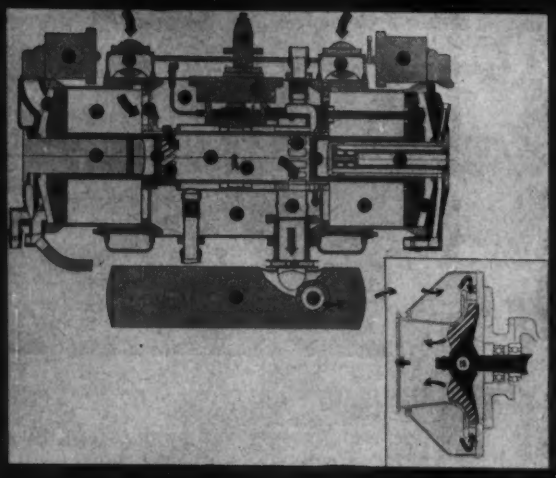


The gasifier is a two-cycle engine having a compression stroke and a power stroke, the exhaust gas being fed to a turbine from which the motive power is drawn. Referring to Fig 6, the combustion cylinder (1) with fuel injector nozzle (2) is water cooled along its length. Air intake ports are at (3) and exhaust ports at (4). Two free pistons (5) are linked together mechanically by a rack and pinion arrangement (6), so that they move inward and outward the same distance and at the same time, the pistons sliding on fixed supports (8), and being oil cooled and lubricated as they move. In the position shown, the pistons have compressed the air in the cylinders (9), and this air, acting as a spring, will force the pistons on the return stroke towards the middle of the combustion cylinder. The fuel injector pump (7) is driven by a cam on one of the racks.

During the compression stroke, air is forced from the compression cylinders (10) through reed valves (11) into the air chamber (12). Entrapped air in the combustion cylinder is also compressed, reaching the ignition temperature at the time fuel is injected. On the power stroke, the pistons are forced outward by the expansion of burning gases, this movement uncovering the exhaust ports first and allowing most of the heated gas to leave the cylinder through the exhaust tube (13). Then the intake ports are uncovered, and air from the air chamber flows through the cylinder, thoroughly scavenging it and mixing with the hot gases in the surge tank (14). The outward moving pistons compress air in the cylinders (9), and this compressed air again provides the rebound to move the pistons inward for the compression stroke. The diluted hot gases flow from the surge tank through a port (15) to the turbine wheel (16), which is the power take-off. As the pistons move outward after the fuel charge has been ignited, outside air is pulled into the compression cylinders through butterfly and reed valves at the air intakes (17).

To activate the pistons for the initial start of the engine, a vacuum pump (not shown) draws air out of the end cylinders to pull the pistons back into the positions shown. Starting cans (18) then provide a measured amount of air under pressure to the cylinders (9), to force the pistons inward for the initial compression. Unlike conventional engines, the free piston engine cannot be motored through a repetitive cranking cycle, but must start on the first stroke of a starting cycle. It is adaptable to a wide range of fuels and an important feature is the flat torque curve.

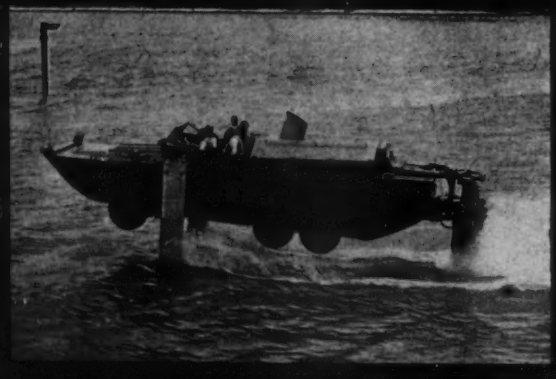




Fluid Power

Fluid power is today very much in the news, and hydrostatic transmissions may well take the place of the conventionally operated gearbox, drive shaft and differential unit. Fundamentally, the system is simple and consists of a pump driven by a conventional engine and a motor or motors incorporated into each driving wheel, or where they will best serve the function of the vehicle. With this basic arrangement, it is possible to have a single control to give variable forward and reverse speeds and progressive braking for more or less constant engine speed. The engine throttle may, however, be linked, when required, to the pump and motor control to give optimum values of speed, torque and economy.

The immediate application of hydrostatic transmission is likely to be confined to tractors and mechanical handling vehicles, where rapid and repeated reversals are required. With a single control it is possible to move the lever rapidly from forward to reverse with no ill effects, the response being instantaneous. Elimination of the complicated, though admittedly tough and reliable preselector gearbox, and the ability to position the power unit anywhere within the chassis, should give wider scope to the public transport vehicle designer.



Air Vehicles

The hovercraft, which has recently been the centre of interest, operates on a principle which is dependent on the close proximity of the ground or sea, and should not be confused with the principle of reaction used in vertical-take-off aircraft, which involves the use of considerable power. The hovercraft employs a cushion of air at relatively low pressure between the ground and the underside of the vehicle, the cushion being restrained by an annular curtain of air. It is obvious that the strength of the curtain must be increased as the ground clearance increases, and to some extent the efficiency of the craft must be related to the smoothness of the ground. Drift is another important factor to contend with, and while this may obviously be controlled within limits, the immediate use of this system for road vehicles seems unlikely. Over water the problem is less acute and the first commercial applications are likely to be in this environment.

The Curtiss-Wright Corp. have developed an air car which is supported and propelled by low-pressure, low-velocity air. Propulsion and braking is accomplished by releasing air through louvres located in the outside of the vehicle, which is capable of turning on its own axis. The prototype vehicle has been demonstrated at 30 m.p.h. and is capable of climbing gradients up to 6 per cent.

A new development in wheel-less air-propelled vehicles has been built by the Ford Motor Co. in the U.S.A. Compressed air, emitted through small holes in three pads on the underside of the vehicle, provides a smooth, almost friction-free ride, in which the Levacar, as it is called, slides on a film of air a fraction of an inch above the surface. Electric controls enable the driver to levitate, start and stop the car by push buttons. Only 15 h.p. is required for levitation, and 1½ h.p. to propel the car at 15 m.p.h.

Although there may well be a variety of novel and practicable systems of propulsion for road vehicles, all these will inevitably lead to the requirement of an entirely new conception of a highway system. Whatever system for propelling the vehicle is adopted, the ultimate control may be invested in the highway itself. In an electronic highway of the future, cars will be maintained automatically on their course, the Radio Corp. of America having already applied for a patent to cover a system controlling both speed and course.

The idea of man-powered flight is not new, but it is only recently that a serious scientific approach to the problems has been undertaken. A fit, athletic human can produce ¼ h.p. for quite long periods; in a burst of maximum energy lasting perhaps only a few seconds, his power output can go up to 2 h.p. There is, however, still the problem of obtaining sufficient initial power to lift the aircraft off the ground, and a possible answer to this is an energy storage unit,[5] which could have many industrial applications.

The flying platform has reached an advanced stage of design, and in many versions is a standard item of equipment of the American armed forces. The configuration varies from a single-rotor to a four-rotor, and among the companies producing these machines are Curtiss-Wright Corp. and the Piasecki Aircraft Corp. Aerojet-General Corp. have been studying a rocket lift device worn as a harness and capable of directional control. The application is directed towards military uses, such as assisting combat troops to negotiate terrain obstacles.

Nuclear Power

Without doubt, nuclear power has made the greatest impact on society within the last decade, but in spite of its applications to power generation it is still in its infancy as far as propulsion is concerned. The biggest achievement in this field has been exhibited by the performance of U.S. submarines, which have proved the feasibility of

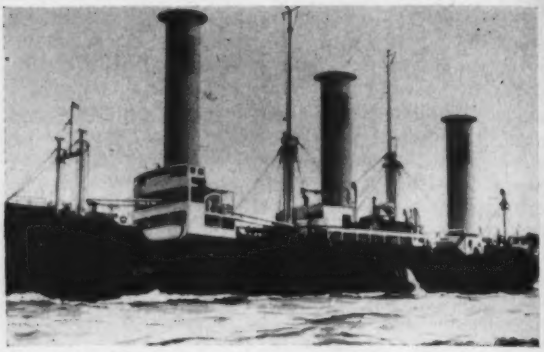


Fig. 8. Motor ship *Barbara* employing Magnus effect.

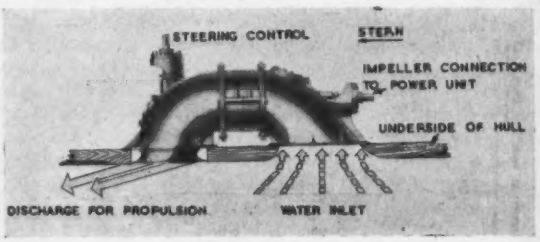


Fig. 9. Gill water propulsion unit.

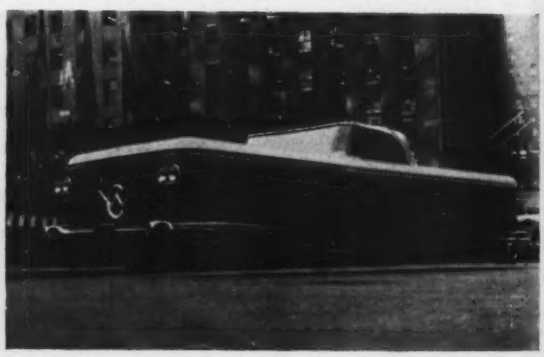


Fig. 10. Curtiss-Wright air-supported car undergoing trials.

Fig. 11. Pinch plasma engine in test chamber (Republic Aviation Corporation).

nuclear energy for propulsion. The next step is its commercial application in the freighter M.S. *Savannah*. The U.S.S.R. icebreaker *Lenin*, with 44,000-s.h.p. turbines deriving heat from pressurised-water reactors, is already in commission. A design concept for a nuclear-powered underwater cargo vessel is being currently explored by Aerojet-General Corp. under a United States government contract.

While the marine applications are the first practical demonstrations of nuclear propulsion, project and design plans are currently being made for its use in aircraft, and flight trials designed to obtain practical data have been conducted in the U.S.A. using conventional power plants for the flying test-beds. In this country speculation has been made as to the possibilities of the Princess flying-boats being used for test work on nuclear propulsion, while it has been claimed that the U.S.S.R. has a fully nuclear-powered aircraft undergoing test flights. The appeal of nuclear-powered aircraft rests on the fact that less than half a pound of fuel (uranium) would be required by a large aircraft for a journey round the world; by comparison, big turbo-jet airliners of today require many tons of fuel for a transatlantic journey. The critical problem is either to reduce the weight of the radiation shield to a reasonable figure, or to limit the shielding to those areas around the reactor which are not directly in line with the passengers or crew. This shadow shielding would protect the occupied part of the aircraft, but in other areas the radiation intensity might be in excess of the safe level. Consequently, with this form of shielding the reactor could only operate when the aircraft had reached a safe altitude, and some form of auxiliary power plant would be necessary for take-off and climb.

Fig. 12 shows the core of an aircraft reactor with which experiments are being carried out at Oak Ridge National Laboratory by the Union Carbide Nuclear Co. The reactor, which stands about 36 in. high with a diameter slightly more than 33 in., was designed to operate at 1,500 kW. The projectile Snap II uses a similar type of reactor for the auxiliary power services, and in this the heat from the reactor is transferred by a liquid sodium coolant to a boiler containing mercury, the vapour being used to drive a turbine and generator which produce 3 kW. of electric power for a weight of 220 lb.

The nuclear gas engine is a new type of power plant, conceived in an effort to evolve a design with a minimum of the complexities and inherent limitations that have been responsible for the high cost characteristics of the nuclear power plants to date. The proposed nuclear gas engine is a reciprocating engine designed for a thermodynamic cycle, in which it compresses a gas and delivers it to a reactor where the gas is heated; the hot gas is then returned to the cylinder in which it is expanded to do work. At the end of the expansion stroke the piston uncovers a port, permitting loop scavenging of the cylinder by a low-pressure gas system, which includes a cooler and a blower to complete the thermodynamic cycle (see Fig. 14).

Fig. 12. Aircraft reactor core (Union Carbide Nuclear Co.).

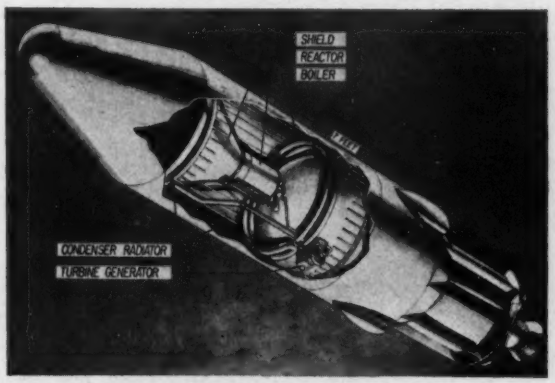


Fig. 13. Snap II reactor system.

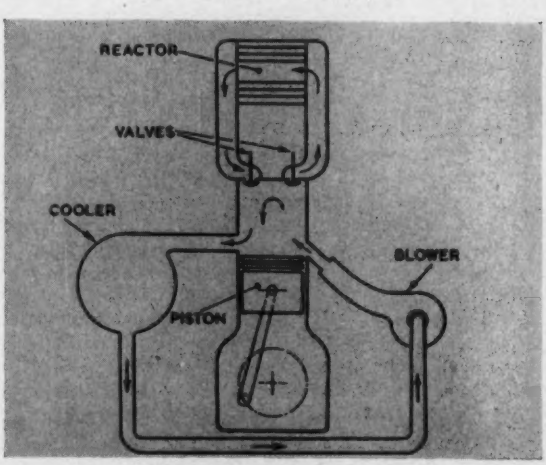


Fig. 14. Diagram of nuclear gas engine.

Rocket Propulsion

Rocket propulsion is one of the oldest forms of providing thrust, although today it is associated with the advance technology of missile and interplanetary flight. Modern science has provided many alternatives to the original chemical type of rocket propellant and it is convenient to divide them into three categories. First the liquid and solid propellants which generate energy from chemical combustion; secondly, those that use nuclear energy as their source of power, and thirdly those that use electrical or electromagnetic devices for the acceleration of mass.

The two principal types of chemical engine are those using solid and liquid propellants. In the chemical reaction, energy is released and is converted into the heating of a working

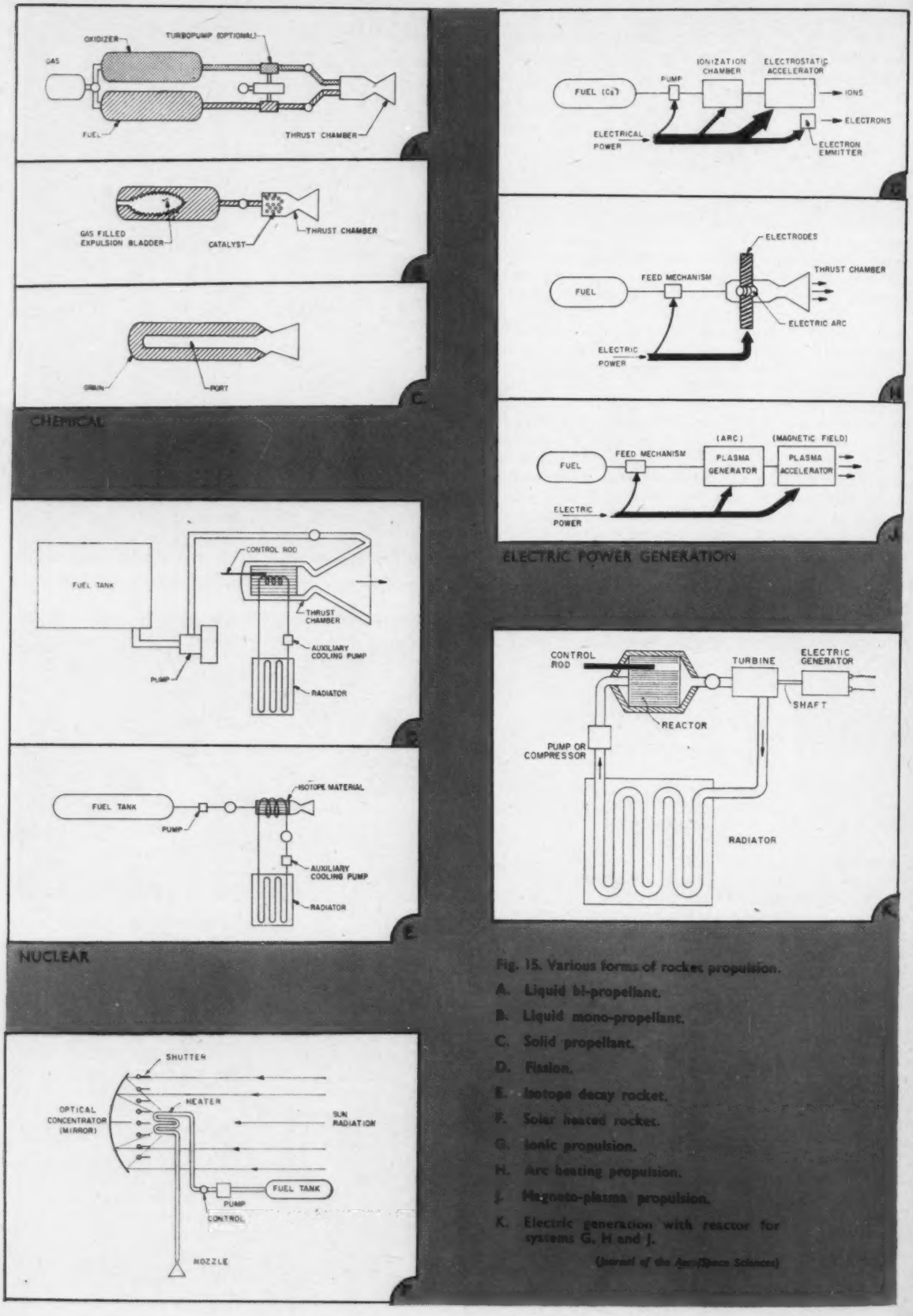


Fig. 15. Various forms of rocket propulsion.

A. Liquid bi-propellant.
B. Liquid mono-propellant.
C. Solid propellant.
D. Fission.
E. Isotope decay rocket.
F. Solar heated rocket.
G. Ionic propulsion.
H. Arc heating propulsion.
J. Magneto-plasma propulsion.
K. Electric generation with reactor for systems G, H and J.

(Journal of the Aero/Space Sciences)

fluid (in this case the reaction products themselves), and this gaseous working fluid in turn is expanded and accelerated in a nozzle to very high velocities.

Consideration has been given to the use of a positive-displacement motor driven by the hot gases from a propellent charge. As a prime mover, this unit combines the advantages of compact propellent energy and moderate rotating speed with the inherently high efficiencies of positive displacement machines. The motor is of the axial piston type, the hot-gas generator consisting of a steel tube holding the propellent charge and an igniter plug to initiate combustion. A rupture diaphragm is provided to prevent a dangerous pressure build-up in the event of the outlet becoming clogged, while the propellant is encased in an inhibitor to ensure uniform end burning.

Propellants are available in various compositions which give combustion-chamber pressures of 500 to 2,000 p.s.i. and temperatures of 815 to 1,370 deg. C. For power levels under 10 h.p. and operating times of up to several minutes, solid propellants seem to have definite advantages in terms of storability, simplicity and energy content per unit weight or volume. For longer operating times, liquid propellants offer the advantages of low specific fuel consumption, which often means lower installed weight and volume, and better control than is at present possible with solid propellants.

A new rocket engine design offers the possibility of reducing by 50 per cent the overall length of current designs, and the illustration in Fig. 17 is a comparison of units in the 1,500,000 lb. thrust category. In conventional engines combustion and expansion of the gases take place in a thrust chamber; in the new design developed by the General Electric Co., of America, fuel would be ignited in a ring of smaller chambers located around the outside base of a conical plug, flight directional control being achieved by varying combustion in one or more of these chambers, thus eliminating the need for the usual positioning mechanism. Unlike clustered rocket designs, these combustion cells would be designed specifically to be integrated into a single power package. A proportion of the gas expansion would occur outside the thrust chambers, and leaving the surface of the plug the supersonic gases would be self-adjusting as surrounding air became increasingly rarefied during ascent.

Today there are three types of nuclear energy release: namely, fission, fusion and decay of radioactive isotopes. In the first type the heat is usually generated by the fission of uranium in a solid reactor framework, the heat being conducted to the surface where it is transferred to a working fluid, usually hydrogen, which is gasified and heated to a very high temperature. Subsequently, it is expanded through a supersonic nozzle and accelerated to very high velocities, and therefore to high kinetic energies. The use of fusion, which is the second way of using nuclear energy in propulsion, could become very attractive, but as yet is not sufficiently understood to be practicable. The third type of nuclear propulsion uses energy from radioactive isotope decay, and lends itself to a relatively simple type of propulsive unit. The decay of the isotopes gives off energy in the form of either alpha, beta or gamma particles or all three, the alpha and beta being readily converted to heat. By choosing the proper isotopes, almost all the decay energy can be transferred to the working fluid. Such materials as cerium, polonium, thulium and thallium can be considered as isotopes for heating hydrogen.

The three basic types of electrical propulsion are, first, arc heating propulsion; secondly, ion propulsion; and, thirdly, a method referred to as magneto-plasma propulsion.

In an arc heating propulsion device the electrical energy is added to the working fluid completely within an arc which is struck between two electrodes. This arc creates a plasma of the working fluid, and as the fluid is blown through the arc it is heated. Similarly, in a solar heating rocket, radiation energy is used to heat a working fluid such as hydrogen.

In the ion rocket, contact ionisation seems to be preferred over other methods because of its relatively good efficiency, simplicity of operation and good prospects for prolonged operation. The resulting ions are accelerated by an electrostatic field of high voltage, and the ions ejected attain very high speeds in the order of 10^6 ft. per sec. A unique approach to a propulsion system, involving the direct conversion of nuclear power to electrical energy for an ionic low-thrust engine, has been proposed by Lockheed Missiles and Space Division scientists. This system would convert electrical energy directly from the thermal energy provided by the nuclear reactor, by-passing the normal energy conversion steps, from thermal-to-mechanical-to-electrical. Cæsium, the fuel supply, would be vaporised and ionised by heat of 1,000 deg. C. produced in a tungsten matrix. The ionised particles then would be speeded up by an accelerating grid of at least 2,000 volts, and ejected from a nozzle at the rear of the vehicle.

In the magneto-plasma rocket, acceleration of a plasma can be accomplished in two ways: by changing or collapsing magnetic fields, and by the interaction of electric current and a steady magnetic field, the plasma being created at high temperatures, usually in an arc. Any of these electrical methods require considerable electrical energy, which may be derived from many different sources. In general, all three of the electrical propulsion systems are relatively unexploited, although under investigation.

Republic Aviation Corp. recently announced a magnetic pinch plasma engine that has been running continuously for more than 118 hr., cycling at the rate of thirty times a minute using 3,000 volts and 675 watts. The engine uses nitrogen for fuel, and turns it into a plasma which is compressed or pinched by a cylindrical magnetic field until it is shot out of the compression chamber at tremendous velocities. Comparing the plasma engine with the ionic engine, the former can attain greater thrusts and operate on fuels that are more readily available and more easily handled. The components of the pinch plasma engine are a small nuclear reactor, turbine generator, space radiator, pinch tube, storage tank of liquid nitrogen and a thrust nozzle. The reactor provides the primary power for the turbine generator, producing electrical energy which is stored in capacitors and then instantaneously discharged in the pinch tube. At this discharge the gas in the pinch tube is converted to a plasma state, in which its molecules are broken up into electrons and positive ions. This heated plasma is reduced to a small area by the magnetic field, and is ejected from the nozzle at extremely high velocity. Each pinch lasts only four millionths of a second, and it is now necessary to translate this concept into a practical working engine by developing a continuous pinching cycle at high velocity.

Future Possibilities

Dr. Teller, of the University of California, has suggested a possible method of harnessing the ionised gases always present in space by forcing all the ions and electrons to spiral in a progressive manner perpendicular to electric and magnetic fields, thus giving rise to a thrust. Although the payload which could be carried in this manner is only a fraction of a lb., it does open up a new line of thought.

Light wave propulsion, the photon rocket, is possible because photons have the property of particles as well as waves. The reflection of light can be considered as photons bouncing off a surface. The photon rocket has been described as basically a strong light source with a reflector, the emission of a unidirectional beam of photons causing a thrust reaction. The required energy is, however, far beyond the present concepts, but nevertheless provides interesting speculation.

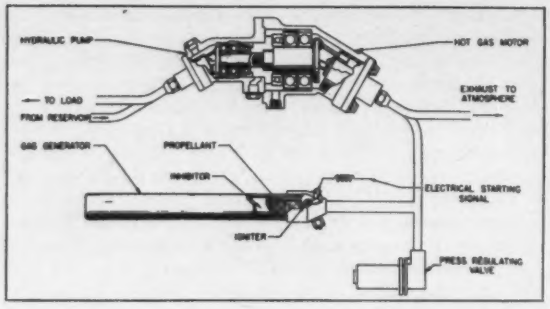


Fig. 16. Hot gas motor system (Vickers Inc., Detroit).

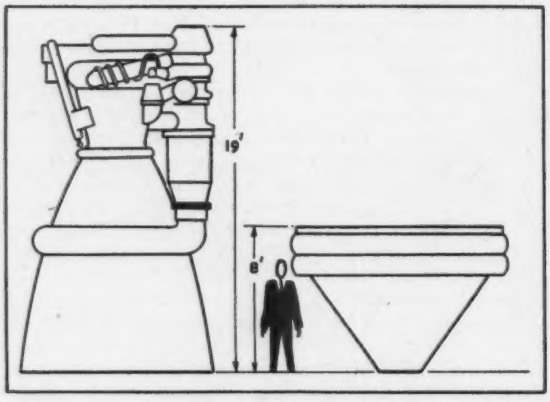


Fig. 17. Comparison of plug nozzle engine (right), and conventional rocket motor (General Electric Co.).

In addition to the types previously mentioned, there is the possibility of direct emission of particles from a nuclear reactor, or electrons from a thermionic source. Again there are combination systems combining features from chemical and electrical systems.

An earth satellite power plant, which utilises solar, nuclear or chemical energy as fuel and can operate unattended for two years or more, is being developed by the Allison Division of General Motors and the Raytheon Co.[6] A laboratory model of the proposed Allison satellite power plant already has been operated successfully on solar radiant energy. Smaller than a desk telephone, a Stirling-cycle engine of 1 cu. in. displacement produces 1½ h.p., sufficient to operate a small radio through an a.c. alternator.

The Stirling-cycle engine under development consists of a displacer piston and a work piston reciprocating in a single cylinder. The cycle begins with the application of external heat produced by any of a variety of combustibles —solar energy, gases or organic materials. Where solar energy is used, for example, a special plastic lens 20 ft. in diameter concentrates the sun's rays and focuses this energy on a window in the engine's heat trap. This heat is transferred inside the engine head to an operating fluid such as air, helium or hydrogen, which is circulated by the displacer piston. Changes in pressure from expansion and compression within the engine, brought about by rapid heating and cooling of the gas, furnish power for the work piston. Solar energy may be stored in heat-retaining lithium hydride to supply energy while a satellite orbits on the earth's dark side.

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1. *Engineering Materials and Design*, February 1960, p. 61.
2. *Engineering Materials and Design*, December 1959, p. 591.
3. *Engineering Materials and Design*, March 1959, p. 148.
4. *Engineering Materials and Design*, August/September 1959, p. 409.
5. *Engineering Materials and Design*, April 1960, p. 225.
6. *Engineering Materials and Design*, January 1960, p. 8.

BEND RADII FOR MATERIALS

IN the fabrication of parts by plastically bending sheets or bars of a given material, it is necessary to know to what inside radius (R) a material of thickness (t) may be bent without fracture occurring during the bending process. This has always been done experimentally in sheet-metal shops by using various tables of R/t values for commonly-used materials. However, with the advent of high-temperature-resistant materials it is becoming increasingly important to treat the subject analytically.

A new theory, developed and substantiated by many laboratory tests, states that failure will occur in the outer fibre of a material being bent when the true strain in the outer fibre is equal to the true strain at the instant of fracture of a tensile test specimen of the same material. Inasmuch as the true strain at fracture can be very easily determined from the conventional percentage reduction of area, the application of this theory is thus greatly simplified.

The following assumptions were made: (a) The fracture strain in the outer fibre of a bending specimen equals that in the tensile test specimen; (b) the material is homogeneous and isotropic, and (c) the bar is in pure bending. The assumption was also made that the neutral axis does not deviate appreciably from the half-thickness of the sheet, which is very valid for R/t ratios greater than 1½.

From experience it was found that the relationship

$$\frac{R}{t} = \frac{50}{A_r} - 1$$

is valid for materials having a percentage reduction of area (A_r), in a tensile specimen, of less than 20. For materials having a percentage reduction in area greater than 20, the displacement of the neutral axis in bending is significant and the derived formulæ becomes

$$\frac{R}{t} = \frac{(100 - A_r)^2}{200A_r - A_r^2}$$

From laboratory experience, it has been found that the empirical relationship

$$\frac{R}{t} = \frac{60}{A_r} - 1$$

is also a very satisfactory relationship for the ductile materials that do have a shift in the position of the neutral axis.

In the derived equation of $R/t = 50/A_r - 1$, the only property which affects the bend radius of a material is A_r, and nothing else. Therefore, this equation is valid for all materials, both metal and non-metal. The strains in the outer and inner fibres during bending are equal in magnitude only when the neutral axis is at the half-thickness of the plate. If the beam is bent in the plastic region, the neutral axis is no longer at mid-fibre and, therefore, the two strains are not the same. However, it can be proved that, for the same R/t, the strain in the outer fibre is much higher than that in the inner fibre. In fact, from practice it is found that compressive regions in bending hardly ever cause failure. Under such circumstances it is justified to use the extreme fibre on the tension side to correlate with the tensile property.

Since plane strain is assumed in the analysis, the proposed equation $R/t = 50/A_t - 1$ would give even closer results with experiment when the width-to-thickness ratio of the plate becomes large, which is usually the case in sheet-metal work.

From an A.S.M.E. Paper No. 59-A-110, by J. Datsko and C. T. Yang.

designer's notebook

PROBLEMS IN DESIGN

Problem No. 7 (May): In a mixing machine, in which a paddle was slowly rotated by an electric motor, jamming of the paddle spindle sometimes occurred. It was found necessary at once to stop the motor and reverse the paddle spindle a few turns by hand to free the blockage. Devise a mechanism whereby, when a certain adjustable torque value to turn the paddle shaft is reached, its direction of rotation is suddenly reversed. The motor shall run continuously in the same direction.

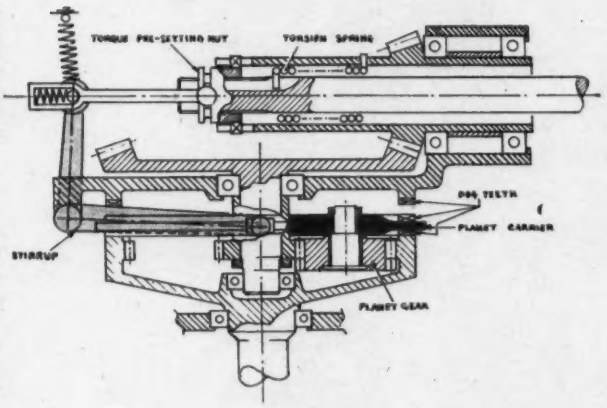


Fig. 1.

Any solution to the above problem must embody some kind of torque sensing device that, when a certain torque value is reached, will bring about a reversal of the paddle shaft. A little thought will show that although a snap action toggle mechanism connected to a torsion spring device or spring-loaded clutch might appear to offer the simplest solution, there is a possibility that if such devices are used all torque can be lost should the torque reversing member get stuck half-way, thus losing all drive.

J. Bottrill's solution (Fig. 1) employs just such a device and, although ingenious, it would appear to suffer from this short-coming. His input shaft drives the output shaft via a bevel gear, torque sensing being by a torsion spring in the annular space between the input shaft and the input bevel gear. Any relative movement between the shaft and bevel gear will wind out a nut on the end of the input shaft, which trips a toggle mechanism. This toggle mechanism operates a bell crank which carries a large stirrup. This stirrup moves a disc-shaped planet carrier which slides on the shaft of the output bevel gear. The planet carrier carries teeth on each side around its periphery. In the forward driving position the planet carrier is dogged to a bell-shaped internally-cut gear connected to the output shaft. When torque exceeds a certain value, the toggle mechanism causes the planet carrier to lift and it becames dogged to the case. In this position the planet gear comes into operation and provides a reduction gear for reverse rotation. Such reverse rotation will continue until the load on the paddle shaft eases. Torque sensing through the reverse planet gear will not, of course, provide the same value as would be obtained through the direct forward drive, but will provide an automatic "try again" mechanism.

H. R. Holliday's drawing (Fig. 4), which is conveniently self-explanatory, also employs an ingenious toggle trip device, this being operated by push rod and lever from a face cam. Torque sensing is by an adjustable friction clutch, and relative movements of the friction elements cause a face cam to rise against a rounded peg. This cam is integral with the push rod which operates the toggle tripping device. Here again, although the mechanism shows great ingenuity, there exists a slight risk that torque could be lost, with everything depending on the toggle snapping over dead centre satisfactorily. If the dogged spool becomes disengaged, all drive is at once lost, and everything then depends on the toggle snap-over spring. Although we appreciate that entries cannot fairly be criticised in the same way as office-prepared schemes, we feel that a single-row ball race at the centre of the drive bevels would be inadequate in such an application.

A. Thompson's solution (Fig. 3) appears to be rather more positive in principle than either of the foregoing, although his drawing is rather more schematic in nature. As in the other two solutions, provision is made for re-engagement when the paddle obstruction has been cleared, although this was not specifically called for. During normal running a cage containing four meshing bevel gears is held in position by roller B on lever A, the input shaft driving the output shaft through the bevel gears and in opposite directions. As the torque on the output shaft increases, the cam attached to the upper part of the cage forces the lever A to the right.

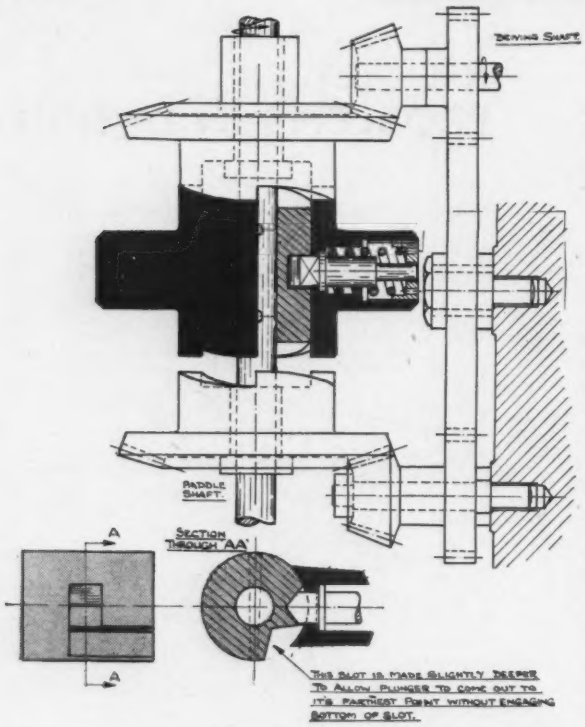
PROBLEMS IN DESIGN

In a special-purpose machine, driven by an integral horse-power electric motor, it was found necessary to incorporate, on the input shaft, a torque tripping device which would disengage the motor when a jam occurred caused by over-size workpieces being fed into the machine. Such a device was installed, but it was found to be ineffective, as it operated on starting. The inertia of the rotating elements of the machine had been ignored.

Devise a simple torque tripping device that will not become sensitive to torque overload until motor and machine have attained about two-thirds of the normal running speed of 1,500 r.p.m. The device should provide for shaft disengagement by mechanical means, followed by automatic switching off of the motor.

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12×12 in., please!), to the Editor, "Problems in Design No. 10 (August)". Closing date September 15.

Fig. 2.


DRIVING SHAFT
PADDLE SHAFT
A
SECTION THROUGH 'AA'
A
THIS SLOT IS MADE SLIGHTLY DEEPER TO ALLOW PLUNGER TO COME OUT TO ITS FARTHEST POINT WITHOUT ENGAGING BOTTOM OF SLOT.

This action causes the dog actuating lever to bring the two dogs together, and the output shaft will then be driven in the same direction as the input. The circular cam ensures that no intermediate condition of no drive can exist. The mechanism is reset for forward rotation by a hand lever.

H. Tooby (Fig. 2) gives us a simple and workmanlike solution, with a manual reset. Torque sensing is achieved by means of a V-ended plunger, urged against a V-slot in a cylindrical piece taper pinned to the output shaft. The spring-loaded plunger is carried in a massive dog clutch component, provided with a knurled enlargement at its centre, which is an easy slide fit on the central cylindrical piece. Referring to the sectional drawing, it will be seen that when the plunger is forced out of the V-slot, by excessive torque, the shaft will then partly rotate and the plunger partly enter, though not make contact with, a slot in the central cylindrical piece, as shown in the lower views. The shape of dog employed will force the dog clutch components apart. The central dog clutch member will then fall until it engages the reverse drive dog, driven by spur and bevel train from the input shaft. Drive will then be taken up by the plunger once more as it comes into contact with the side of the deeper lengthwise slot in the central cylindrical member. This mechanism relies on the stored kinetic energy of the heavy dog clutch member falling into engagement, a principle that would probably work well if fits were easy and the working conditions were not too dirty. It has the disadvantage that the motor would have to be stopped before the re-setting operation could be safely carried out.

The entry we considered most elegant of all was that coming from **H. W. Jones** (Fig. 5), for it embodies a fine system of torque sensing and an absolutely positive torque reversal mechanism. The general appearance of the layout, moreover, is in keeping with the kind of mechanism most suited to such machines as mixers, which often work in dirty con-

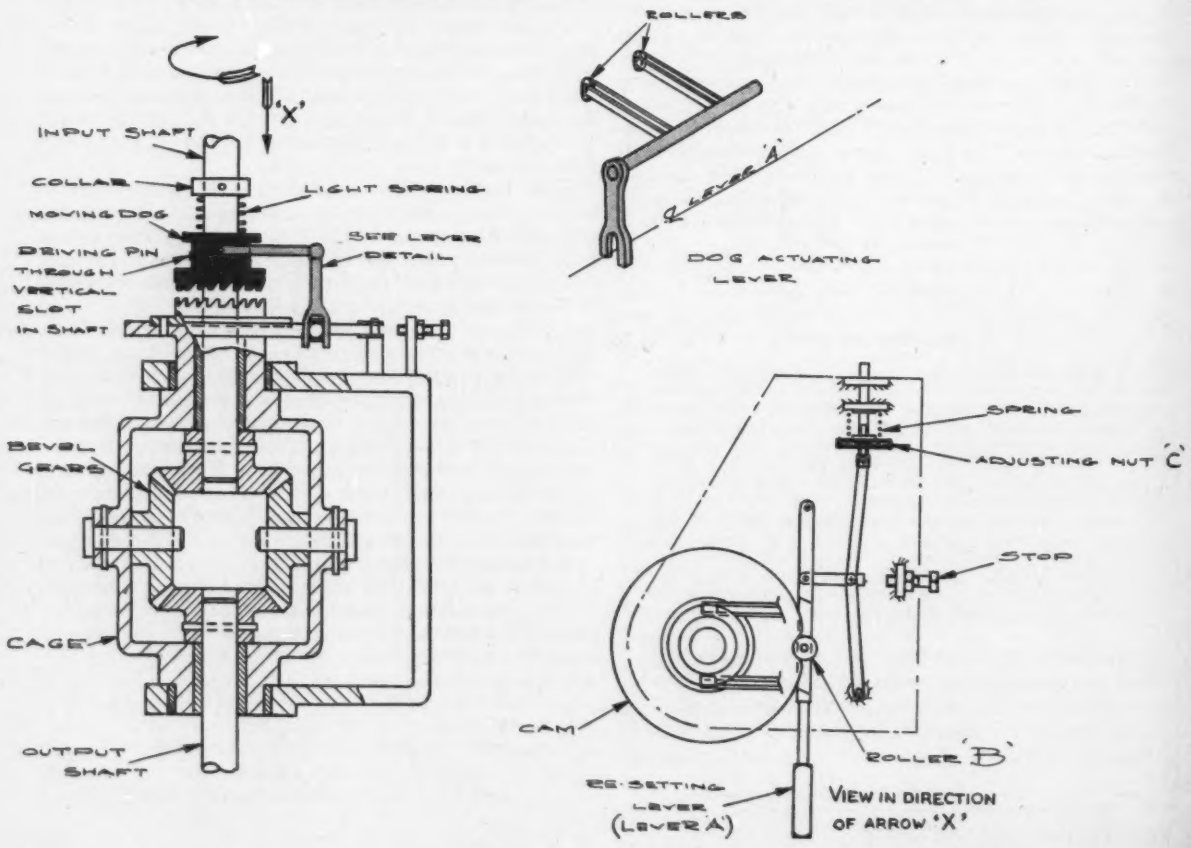


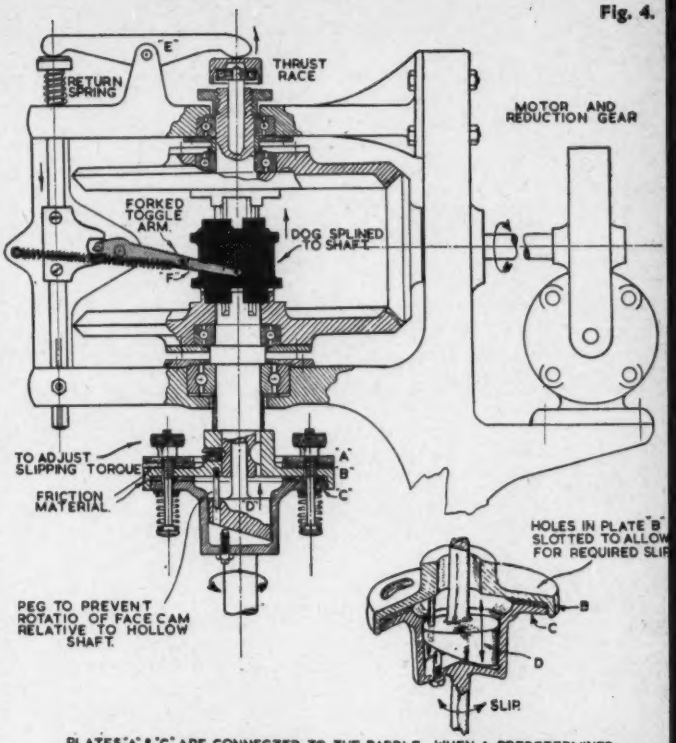
Fig. 3.

ditions and must be fully enclosed. It goes beyond the requirements of the problem as set and provides for double reversal.

A flange-mounted motor drives, through bevel gearing, the contra-rotating clutch plates C_1 and C_2, which are free to rotate on a floating worm shaft and are supported in the two angular-contact ball bearings. The driven member of the clutch D is free to slide on the worm shaft, but is restrained from rotation by the sliding key K. Integral with the shaft is a raised ridge which is engaged by the spring-loaded pawl P. According to which side of the ridge the pawl is, the driven member D will be pressed against one of the clutch plates C_1 or C_2, the reaction on the shaft being taken by a shoulder. Adjustment of the two springs is provided by screw S, and the pawl is restrained from sideways movement by machined cut-outs in the insert block E, shown in the bottom right-hand view. Axial thrust from the worm is transmitted through the pawl into the driven member, and assists in maintaining sufficient pressure on the clutch lining to drive the worm shaft via the sliding key. As the thrust in the worm shaft (which is a direct measure of the torque in the paddle spindle) increases, the shaft slides axially through the clutch plates, causing the pawl to ride up and over the ridge, re-engaging on the other side. Some adjustment of the pawl point would, in practice, prove necessary, but it will be seen that with this arrangement drive is positive right up to the point of torque reversal, when the pawl will then have passed over the ridge and reversal of rotation will be initiated. It will be seen that four separate ridges are available in case of wear, and Mr. Jones suggests that the mechanism be oil filled.

Torque sensing by a spring-loaded worm gear has also been successfully employed for the operation of gate valves, and provides a positive degree of tightness. When the required degree of tightness has been achieved, a micro switch shuts off the driving motor.

Fig. 4.



PLATES "A" & "C" ARE CONNECTED TO THE PADDLE. WHEN A PREDETERMINED TORQUE IS REACHED "A" & "C" SLIP RELATIVE TO PLATE "B" KEYED TO THE DRIVE SHAFT.
FACE CAM "D" RISES AND, VIA LEVER "E" OPERATES THE TOGGLE ARM "F" WHICH THROWS THE DOG CLUTCH INTO ENGAGEMENT WITH THE OTHER BEVEL GEAR, THUS CAUSING THE PADDLE TO REVERSE.
WHEN THE SLIPPING TORQUE IS REACHED IN THIS DIRECTION THE CLUTCH SLIPS BACK, "D" RETURNS AND THE DRIVE IS AGAIN REVERSED.

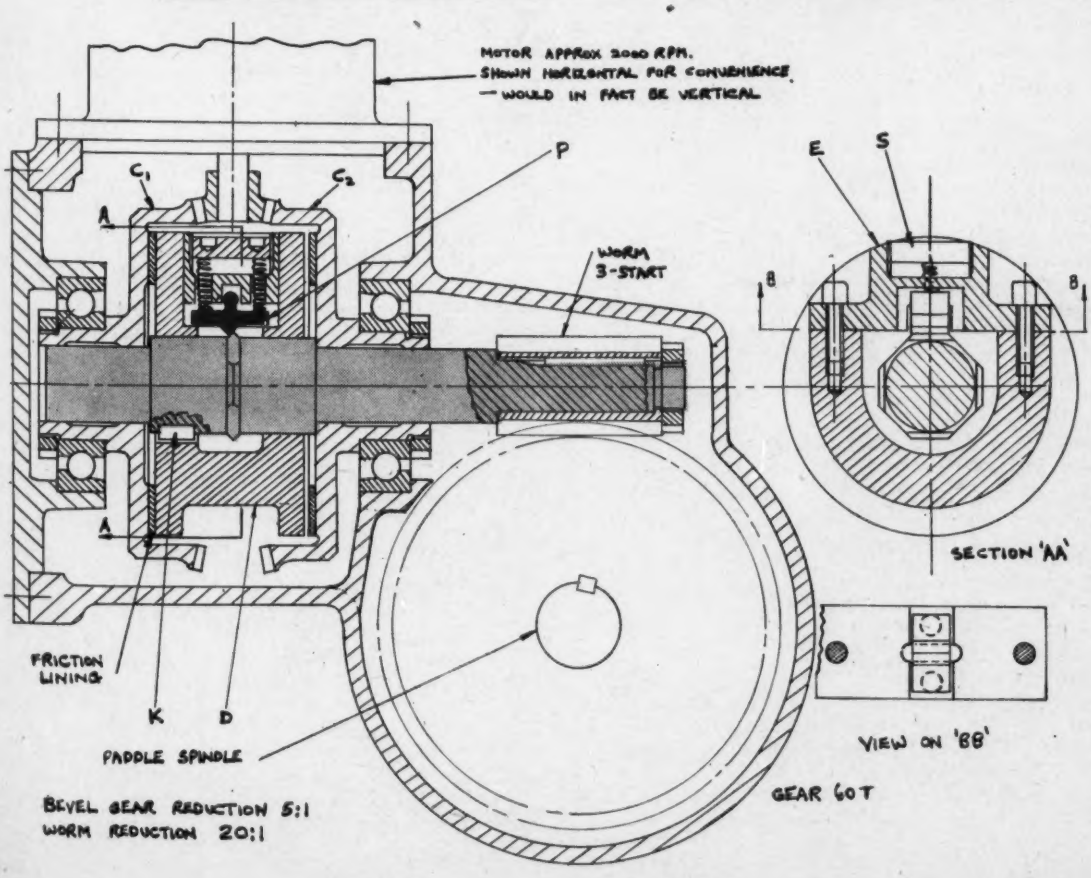


Fig. 5.

PROGRESS IN RAIL TRANSPORT UNIT DESIGN

Modern materials are having an increasing influence on the design of rail transport units. This article discusses the possibilities in the light of availability

by G. W. McARD, A.M.I.Mech.E.

WISE selection of the various materials which go into the construction of a power unit for transport purposes is not governed by invariable rules. Many factors may arise to prejudice the position and cause a compromise to be adopted, though such will undoubtedly be revealed at a later stage, either by a drastic reduction of the useful life of the machine, or of its efficiency.

During recent years the steam locomotive has been regarded in some quarters rather disparagingly, its oil-engined rival being exalted to premier place. However, designers of the steam unit may yet come back into their own as the result of modern research and co-ordinated efforts. A machine such as that seen in Fig. 1, capable of developing 5,000-6,000 h.p. in a single unit, has not been produced by out-of-date methods and designers, but by men who were acutely aware of the necessity for selecting just those materials which would enable their target to be reached—maximum power at a minimum of first cost with, later, the minimum of maintenance.

In every locomotive design the weight on the driving axles and the tractive power at the rail must bear a definite relation to each other, and this factor, i.e., the adhesive value, can never be ignored. If for some reason a designer fails to provide a sufficient load, slipping will occur, and the locomotive will be unable to use efficiently its higher range of power. But by a discriminating choice of materials, maximum power can be provided with the minimum finished total weight, and a drawbar h.p. developed which will not only ensure schedule times being kept, but even improved upon.

For rolling stock in general there is a further factor to be remembered; viz., the stability of each vehicle in the train. This is most important at all times for the comfort of the passengers, but their safety also demands the utmost care where high schedule speeds operate on a track in which curves are sufficiently numerous to expose any defects in riding; a centre of gravity which is too high relative to the rail gauge may be even more dangerous than where it is too low.

Underframe Developments

Coming to the more detailed aspect of the subject, interest is usually focused on the underframe, which will have to support the power unit and its auxiliaries, or, in rolling stock generally, the revenue earners, i.e., passengers and freight. Naturally these structures will be designed for all units to give ample strength for the load to be carried and the rail shocks sustained, suitable factors of safety being included in the calculations to allow for a measure of overload. Where earlier locomotive practice included a structure riveted throughout, a modern steam-locomotive frame can be produced as an integral unit with all cylinders included, and delivered direct from the steel foundry to the builder's works ready for the machining and finishing operations.

Underframes for high-capacity locomotive tenders in the U.S.A. also are produced as single steel castings, each functioning additionally as the base of the tank itself, with all special features such as draining well and facings for valves and operating mechanisms cast on ready for machining. The frame for the locomotive seen in Fig. 1 is shown as a finished unit ready for transference to the erecting shop, where it will receive the boiler and other equipments (see Fig. 2). The overall length of this frame is 77 ft. 9½ in. and its total weight 97,620 lb—surely a masterpiece in steel creditable alike to designer and producer. This type of frame is greatly appreciated by all railway operators, because of the absence of the troubles experienced in the old days with riveted structures.

An alternative design of underframe commonly used for diesel vehicles is that afforded by welding. Each of the principal members—the two solebars—may be formed from a continuous plate deeper in section in the more heavily loaded zones, the entire length being reinforced by top and bottom flanges welded on. These longitudinals will be tied together at intervals by welded cross-stretchers positioned suitably to serve for supporting auxiliaries, and at the ends by welded headstock structures. To secure strength plus lightness, the body and the underframe are designed and built for many vehicles to function as an integral unit, each serving to brace the other, the materials for each being chosen with the object of obtaining the utmost advantage in regard to the weight/strength ratio.

Design Research

If tests now proceeding on British Railways with Dr. Giesl's special design of exhaust ejector prove as successful as anticipated, a new era in steam rail transport might well be opened up, in which case the excellent research work accomplished by the specialist makers of copper firebox plates will be amply justified. For many years the seams of these plates were riveted, but now that it is possible to weld these joints successfully, many troubles formerly encountered have been eliminated and repair work, when necessary, greatly simplified.

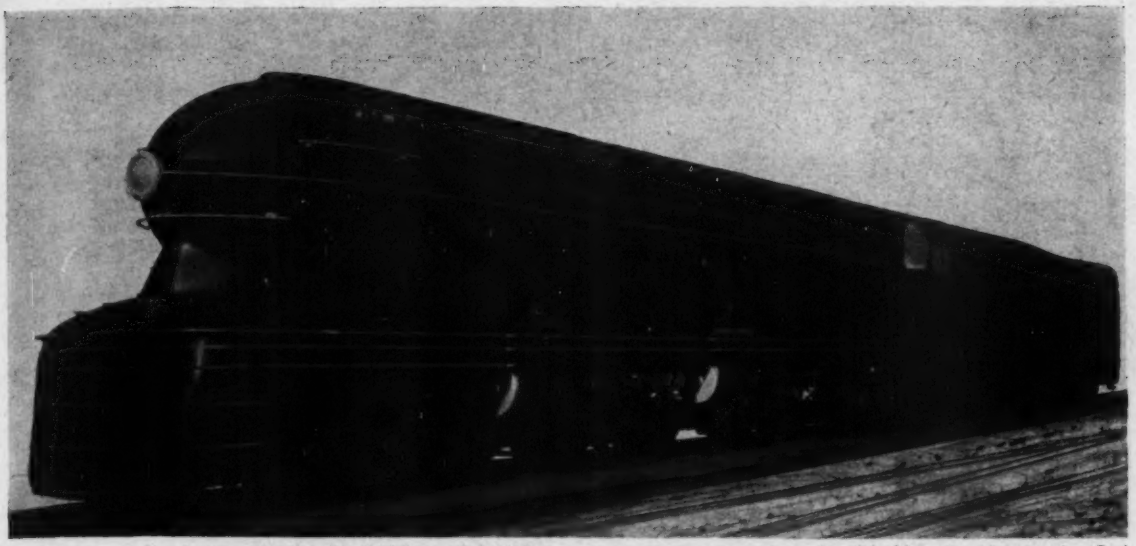


Fig. 1. Pennsylvanian Road high-speed 6-4-4-6 type express passenger engine, class S.1. (American Locomotive Co.)

A further factor which has involved considerable research in steam locomotive operation is that known as galvanic corrosion. This will occur in any locomotive boiler in which steel and copper plates are used and are in electrical contact by virtue of inferior water which serves as the corroding medium, or the electrolyte. Studies of galvanic corrosion have made it possible to arrange models in what is termed a galvanic series, to show the tendencies of different metals and alloys to form significant galvanic cells and the probable direction of the galvanic effects. On some occasions locomotive users and designers alike were faced with a problem for which there was only one solution—an alternative water supply of more pure composition. In one such case, from the writer's personal experience, the copper fireboxes using the original water only lasted a few months, notwithstanding every resource tried to lengthen the life.

During the last fifty years superheated steam has become the vogue for all locomotives except those used exclusively for shunting duties. This has proved beneficial to the operator by virtue of the increased power and speed afforded, but many difficulties arose in the early years through the attempt to continue the use of the same materials as previously had been quite successful for the saturated steam machine. Every designer recognises the need for a wide range of gunmetal and bronze mixtures, extreme cases being the valves fitted on steam and water pipelines and the axlebox bearings. The introduction of superheated steam, however, created a fresh problem which was only solved by the discovery of a metal capable of resisting the disintegrating action of high-temperature steam, viz., Monel.

A close study of the forces set up by the revolving and reciprocating masses in a steam locomotive has revolutionised the ideas of all locomotive designers in regard to the wheel balancing methods hitherto regarded as fully established. Two approaches were made: (1) how to reduce the weight of the masses, revolving and reciprocating, and (2) the proportion of these to be balanced. The investigation was prompted initially by the knowledge that, in certain phases of the driving wheel's rotation, it lifted appreciably from the rail, as seen in Fig. 4; as the result of tests in the laboratory and on the track, the design of all parts involved was improved, sometimes by a change of material, also the introduction of roller bearings, and the desired end, i.e., safer and more comfortable riding, was achieved.

The investigation was carried out by the then L.M.S. Railway, who arranged for an express engine and its load to enter at high speed a certain section of track which previously had been specially greased for the test on their upper surfaces. By this means it was possible to combine a high rotary speed of the wheels with a relatively low speed of movement of the train.

A modern design of crosshead capable of sustaining a piston load of 45 tons under full steam pressure is shown in Fig. 3, and by various means it has been possible to effect a reduction of weight, of reciprocating parts alone, for big engines equal to not less than 50 per cent of the original basis. The changeover from a carbon steel to a modern alloy steel such as nickel chrome can work wonders in the sphere of the coupling and connecting rods, and an examination of these for an engine such as Gresley's Mallard, which, incidentally, still holds the world's speed record at 126 m.p.h., is well worth while.

New Materials

In almost every branch of rail vehicle design aluminium is playing an increasingly prominent part, top-grade steamers in the U.S.A. having their boilers insulated with Alfol, with which a reduction in weight for a unit like that seen in Fig. 1—4,000 lb. when using magnesia blocks, but for Alfol only 65 lb.—seems phenomenal, even allowing for the fact that the clothing sheets also were changed from steel to aluminium. Units for the rail transport of various types of fluid cargo have their cylindrical tanks made of aluminium, which has been found to give excellent service, whilst doors and a host of other fittings in light alloys are now almost standard practice for many passenger vehicles, where in earlier days these were formed from castings and pressings in the heavier metals. Among the advantages derived from the change may be mentioned the higher payloads and longer service life, and, equally important, the elimination of corrosion.

Reference to corrosion brings to mind the remarkably valuable services which have been rendered by high-grade wrought iron, through its effective resistance to corrosive action. One of these, known to the trade as Low Moor best Yorkshire iron, is recommended highly for the shells of locomotive boilers in which water of inferior grade will definitely be used, and the claim is made that these will last as much as five to ten times as long as mild-steel shells. Additional value lies in the ability of this material to withstand shock better than mild steel, and it also affords an excellent medium for those parts in which a perfect weld is

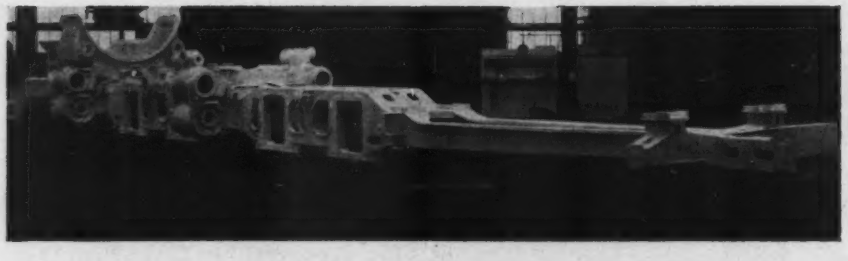


Fig. 2. Locomotive frame in cast steel for the engine shown in Fig. 1.

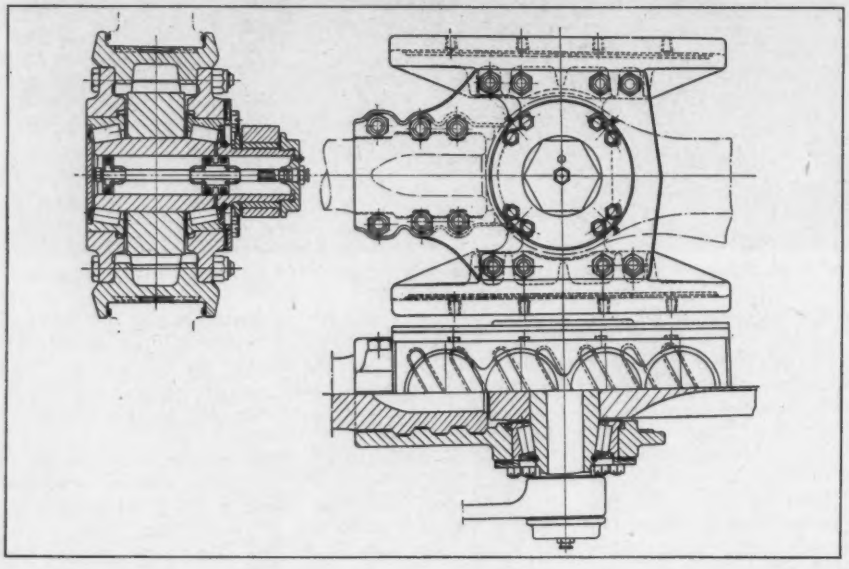


Fig. 3. Crosshead design for South African Railways class 25 locomotives. (North British Locomotive Co.)

an essential feature in production.

In first-class locomotive designs distinction must be made in regard to the use of case-hardening steel and high-tensile steel for many details which work in partnership. By correct planning of equipments which are costly to produce, as, for example, the rods and links which combine to form the valve gear, wear is concentrated on the more easily renewable bushes, pins and facing washers, thus safeguarding the forged members for an almost incredibly long service life.

The main bearings on all axles have been the object of a revolutionary change since the introduction of roller and ball bearings to this field, and the percentage of hot boxes where these anti-friction units are applied has fallen considerably. In many long-distance expresses these anti-friction bearings function so effectively that lubrication problems peculiar to earlier days are no longer experienced, and the driver is freed for other tasks.

In no sphere, perhaps, have there been greater advantages reaped than in that of the spring suspension, by virtue of the changes made in the grade of steel used for the spring plates. Research in laboratory and testing room has been amply confirmed on the track, and the swing from the earlier plain carbon steel to an alloy steel such as silico-manganese or chrome-vanadium, has paid good dividends in the form of almost complete freedom from failure in service and longer working life of the springs.

The development of diesel rail units has introduced many new ideas and been profitable to those designers with adequate mental flexibility, but one of the big problems which has given anxiety in almost every new design is that of weight restriction, especially in such units as those shown in Figs. 6 and 7. The solution is only achieved by concentrated care in the selection of the materials to be used in the manufacture of the numerous details, especially the larger sections such as underframe and bodywork for housing engine and auxiliaries. An appreciable reduction of weight is possible in these last two sections, but care is needed when deciding the thickness of sheets lest the further problem of drumming arises. This can be particularly troublesome with an engine like the diesel as the main power unit, owing to the vibration created at certain speeds.

The diesel engine builder can give considerable help to the hard-worked vehicle designer who, of course, takes full responsibility for keeping his total weight to that specified by the client. For engine mechanisms only the finest quality steel is used, but detail profiling on a 2,000-h.p. unit can save quite an appreciable amount. The use of aluminium, cast and wrought, Elektron and other light alloys has saved handsomely on the total weight of big units, and added years to the service life of the machine.

Had plastics been available thirty or forty years ago, the designer who dared to advocate their use for rail vehicle construction would have been a brave man. Yet today this resource has been a very good friend to the designer in many directions, one good illustration being the domed ends of rail coaches, which formerly were beaten out from steel or aluminium sheet at considerably greater cost and weight. The use of polyester resin/glass fibre provides the means of self-colouring, which eliminates any necessity for painting and also the risk of corrosion. This is but one example in which the plastics industry helps the rail unit designer, a few of the others being moulded window surrounds, control panel boxes, instrument cases, toilet seats and fixtures and others too numerous to mention.

The extensive use of rubber today is in contrast with the earlier part of this century, when its value, so far as rail service was concerned, was negligible. Yet with the reintro-

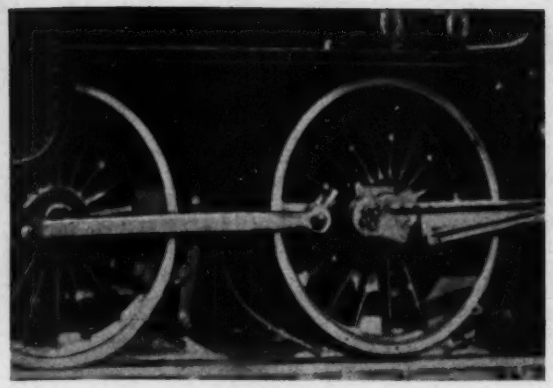


Fig. 4. Locomotive driving wheel, as filmed at a rotational speed of 105 m.p.h. (London Midland Region of British Railways.)

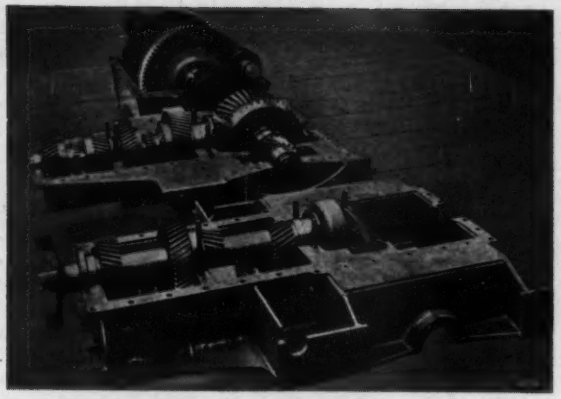


Fig. 5. Gear drive for diesel mechanical shunting locomotive. (Hunslet Engine Co.)

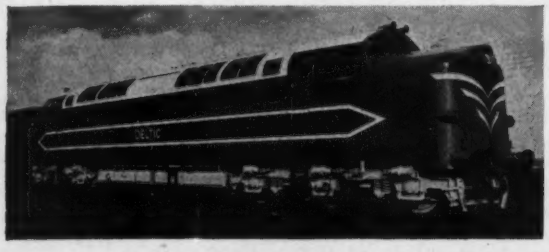


Fig. 6 (*above*). Deltic class diesel-electric locomotive. (English Electric Co.)

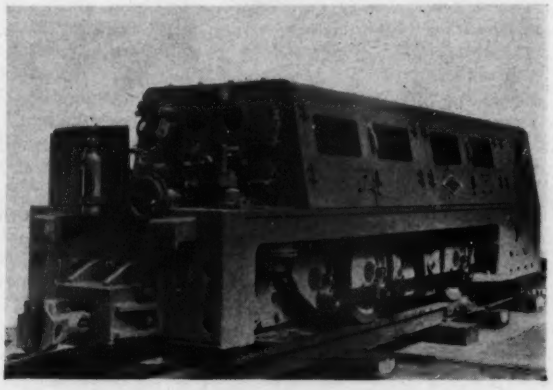


Fig. 7 (*right*). 100-h.p. mines locomotive. (North British Locomotive Co.) Weight in working order: 15 tons with 100-h.p. diesel engine.

duction of the flat-bottom section of steel rail on our main lines, rubber pads fitted between rail and sleeper appear to have solved the difficulty of the creep tendency revealed in many lines as the result of the tractive pull exerted by the locomotive or other hauling agent. Its use here also serves to protect the concrete sleepers from much of the impact shock previously sustained during the transit of heavy vehicles. Other examples in which rubber has proved itself a valuable ally include the many types of Silentbloc bearing, so well known as a vibration dampener; Spencer-Moulton springs for drawgear and buffing units; Dunlopillo cushions for coaching stock, and the auxiliary springs now fitted between the underframe and its main bearing springs.

The flat-bottom rail, already referred to above, when previously used was limited in length by the rolling capacity of the steel mills, the continuity of the line being effected by the use of fishplates and bolts. The desirability of welding the joints has often been discussed, and is now being put into practice on many systems, including certain sections of British Railways, thus eliminating much of the rat-tat-tat so familiar to travellers as the wheels cross the gaps between adjacent rail ends. The prime reason for welding, however, is to spare the moving structures as much as possible from the destructive effect of these oft-repeated shocks, and results reported from systems with relatively long experience of the newer method justify the change.

Reference has already been made to the use of concrete sleepers; few railway engineers could have visualised, fifty years ago, the part concrete would ultimately play in a sphere which seemed to hinge so extensively on the supply of steel and other metals, also timber. Yet the relative shortage and high cost of these materials consequent upon two major wars have been instrumental in bringing concrete well to the front for bridges, workshops complete with their roofs and floors, and innumerable other fields peculiar to railway operation. Possibly the latest branch of research in this field is that now concentrated on the exploitation in concrete of those structural principles which give the shells of eggs or crustacea their remarkable strength.

An experience shared by the writer in 1930s enables him still to appreciate the value of the work done in the research sections of leading glass producers. The incident occurred on a trial run of a heavy prototype diesel-electric railcoach, when it was travelling at around 60 m.p.h. The driver's lookout window, which extended the full width of the cab, struck a fully-grown pheasant in its flight across the track, and although the bird was killed, the window sustained no damage, being made of special armourplate glass. Strength and toughness to resist shock are but two of many advantages now available to a modern designer, with that other welcome addition of perfect visibility and freedom from distortion.

With the coming of diesel-engined units, in which mechanical transmissions are used (see Fig. 5), the designer has a further responsibility in ensuring that his gearbox and clutch are provided with the most dependable oil for long service operation. Many transmissions include one or more worm drives, and from the writer's experience in the selection of lubricants it would certainly seem that many gears, like their designers, can be extremely temperamental. One oil which was used most successfully by our outside staff had a castor base, yet with less onerous duties many other boxes ran hot on this oil, but ran perfectly for thousands of miles on a good mineral oil. It is, of course, well known that considerable help in this direction can be afforded by skilful arrangement of the ribs on the body of the gearbox, but experience has proved that oil is a major feature in successful running.

JOINTS FOR HIGH-TEMPERATURE CREEP

BY increasing the understanding of creep behaviour, it is possible to design structures which can be used in creep-producing environments with a minimum of mechanical testing. Creep is a continuing deformation under stress, characteristic of all metals at sufficiently high temperatures, and for structural metals it usually becomes significant at temperatures several hundred degrees above room temperature. At still higher temperatures it so weakens these materials that they become useless for engineering purposes. Between these limits, creep is a very important consideration in design.

Although considerable experimental work had been done to determine creep behaviour in materials themselves, little was known until recent years about the effects of creep on built-up structures. To evaluate the creep behaviour of structures, a series of investigations has been undertaken by the U.S. National Bureau of Standards, starting with an elementary joint and expanding to include more complex structures.

CREEP RUPTURE OF JOINTS—Under static conditions the strength of a joint is normally calculated from the ultimate tensile, shear and bearing strengths of the material involved, and the strength of the joint is taken to be the smallest of the loads required to produce each mode of failure. Creep rupture strength, however, decreases both with temperature and with the length of time that the joint is at a given temperature, and the specification of these variables allows the loads causing failure to be calculated.

Very often, creep rupture strengths of the materials are known for tension loadings only, and from this the efficiency may be estimated, i.e., the ratio of the strength of the joint to the strength of an unriveted sheet of the same material. The assumption that this ratio is the same under creep conditions as under normal static conditions implies that the variation of the bearing and shear strengths with temperature and time is similar to the variation of the tensile strength. The creep rupture strength of a joint is therefore the tensile creep rupture strength of the sheet material multiplied by the joint efficiency.

CREEP DEFORMATION OF JOINTS—For many structures, joints which do not rupture within the specified lifetime are not sufficient, as they must be rigid enough to prevent excessive deformation. Designing for allowable deformation is facilitated by the stress-sensitive nature of creep; relatively large changes in rate of deformation result from small changes in stress.

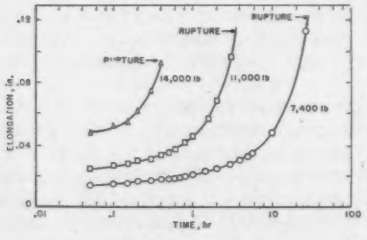
EFFECTS OF VARYING LOADS AND TEMPERATURES—In many applications, joints are subjected to conditions of varying loads and temperatures, where calculation of the time to rupture or the time to reach the specified allowable deformation desirable. For this purpose, the history of the joint is divided into small increments of time during which load and temperature may be considered constant. When the creep behaviour in any increment is not affected by the conditions in previous increments, rupture or the specified allowable deformation is reached when the summation of the life fractions reaches unity. In the general case, creep is a function of past history, so that the limiting condition is reached when the summation of the life fractions equals some quantity other than unity, this quantity being called the time ratio.

The most desirable means of estimating the time ratio for a joint is to base it on the behaviour of the material of the joint, the time ratio for a joint being considered equal to the time ratio for rupture of the material of the joint under identical conditions.

EFFECTS OF PRIOR CREEP—A material specimen that has undergone a certain amount of creep would ordinarily be expected to yield more rapidly to momentary periods of overload than would a "new" specimen. It has been found, however, that moderate amounts of prior creep produce a change in tensile properties which is usually small and sometimes beneficial, similar behaviour being observed for riveted joints. For design purposes, it is generally satisfactory to consider that the reduction in strength of a joint due to prior creep is equal, percentagewise, to the reduction observed for the material from which the joint is fabricated.

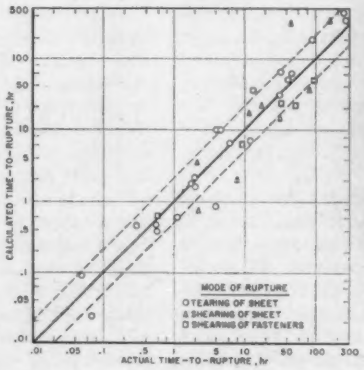
ACCURACY OF CALCULATIONS—The methods that have been described make it possible to design riveted joints for creep conditions without testing the joint. However, the dependability of the design can be no better than the materials data upon which it is based. The strength of a joint that is required to have a specified lifetime under given temperature conditions can be determined within 10 per cent, but, in calculations for a given load and temperature condition, inaccuracies may be as high as 2 to 1, showing the stress-sensitive nature of creep, whereby small variations in stress lead to large variations in lifetime.

From a report by the U.S. National Bureau of Standards.



Representative creep curves obtained for three riveted joints of titanium alloy. The tensile loads remained constant until rupture, the test temperature being 430 deg. C.

Comparison of calculated times-to-rupture for riveted aluminium alloy joints and actual results obtained from tests.



Creep rupture failures of large bolted joints of forged aluminium alloy at 200 deg. C; (left) a brittle fracture of 2014-T6 alloy, and (right) a ductile failure of 7075-T6 alloy.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

Television Projection in Colour

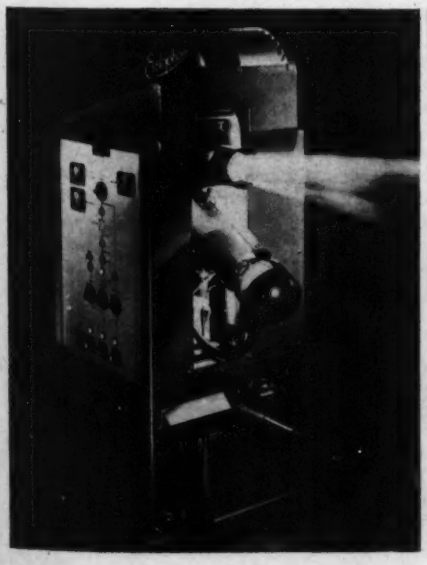
IN a conventional television receiver an electron gun is acted on by the television signals being received so as to produce a scanning beam. Unfortunately, the brilliance of the image relies on fluorescence, and normally the size of the screen depends on the size of the tube. Although optical magnification of the image produced by a small high-intensity tube can be enlarged for projection on a wall, this system seems to be out of favour compared with the larger type of tube.

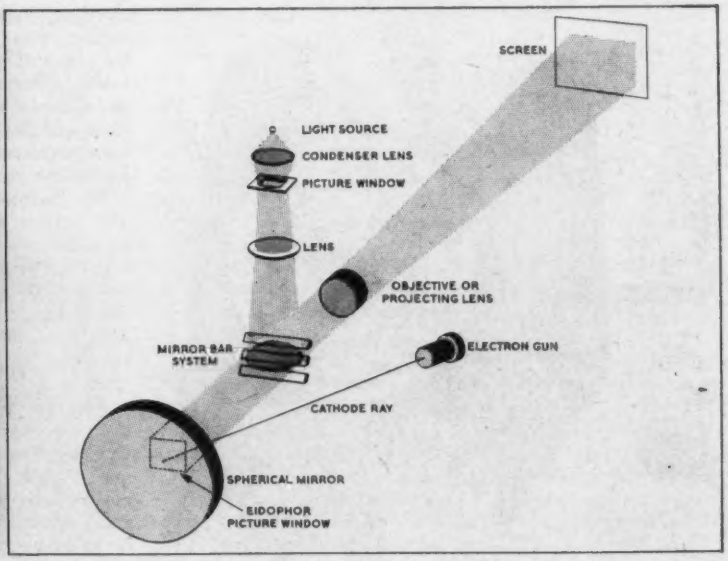
In the Eidophor system, which was recently demonstrated in London, a stream of electrons is used to bombard a film of oil on a slowly rotating mirror of concave shape. The effect of this bombardment, which is carried out by a cathode ray tube of a special type (but somewhat similar to that found in an ordinary television receiver), is to produce a series of transient indentations in the thin oil film. The strength of the electron beam is sufficiently great to exert an electrostatic force which physically alters the uniformity of the oil at the point of impingement. It is this momentary alteration in the reflecting properties of the oil-coated mirror by the scanning beam that is relied upon to produce corresponding alterations in a beam of light from a high intensity light source, in this case a xenon arc operating in a quartz glass tube.

The accompanying diagram shows the way in which the optical system works. Light from the xenon tube is directed on to a system of mirror bars situated so as to reflect it towards the spherical mirror and, under unexcited conditions, reflect it back again via these mirror bars to the light source. An objective lens focuses any light that may escape through the bars on to a screen, using the ordinary projection system, so that a magnified image of any available light is seen on the screen. As the size of the indentations produced in the oil layer on the revolving mirror by the scanning beam is proportional to the strength of the beam from instant to instant, it follows that the light reaching the concave mirror by reflection from the mirror bars is in accordance with the location and size of these indentations. In this way the image seen on the screen, deriving its light from a high intensity source as in a cinema projector, is a magnified image of the rapidly changing pattern of indentations. The oil used has been chosen and compounded in such a way that it is a good enough dielectric to enable it to be affected by the electron beam so as to produce adequate dimples or indentations, but at the same time is a conductor, so that charges on its surface engendered by the electron beam will rapidly leak away. The revolving mirror and electron gun assembly is housed in a metal case and is continuously evacuated by a pump.

The system so far described concerns image formation without colour. At present the system can only be used on a closed circuit for colour television, owing to the absence of transmitters putting out signals on the Eidophor system. For colour work, two rotating colour wheels, one in front of the camera and one in front of the projector window, are used. As in the original Baird system, these are arranged to run exactly in step. Each colour wheel is simultaneously scanning the image being viewed, the one directly and the other in front of the projector window. The system relies on "after-image effect"; as the eye superimposes the rapidly succeeding images in red, blue and green which it sees on the screen, a full colour effect is achieved.

The basic principle of the Eidophor system was invented by Dr. Fritz Fischer, of the Swiss Federal Institute of Technology, in 1939, but only recently has it been brought to the stage of public demonstration. It is manufactured by the firm of Dr. Edgar Gretener A.G. of Zurich. Although at present it needs the services of a skilled operator, and is only suitable for lectures, etc., future developments may make the use of this system more widespread.





Electronic Device for Inspection of Rivet Heads

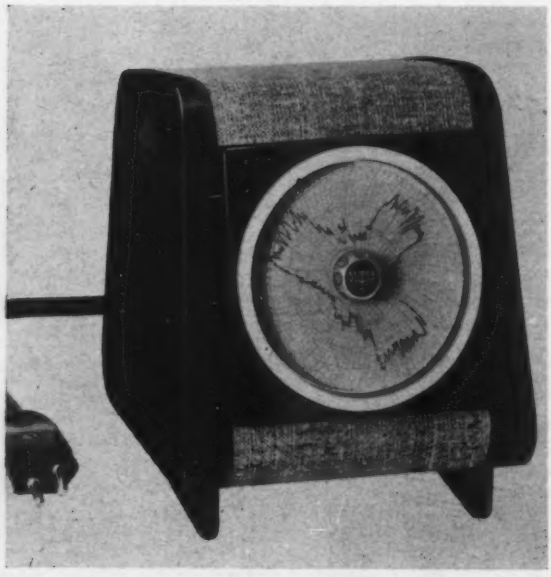
AN electronic rivet-head inspection device, developed by electrodynamics staff engineers of the Boeing Transport Division, U.S.A., is claimed to provide increased accuracy and reduce inspection time by two-thirds over former hand-gauging methods. It indicates, to a ten-thousandth of an inch, any deviation from standard in inspection samples of the hundred million or so aluminium, stainless steel, titanium and other rivets that Boeing buy every year.

Capable of measuring individually a batch of fifty rivets, the new device gives a figure, automatically averaged and computed, governing acceptance or rejection for some 332 different categories of rivets, which must meet extremely close dimensional tolerances. The electronic and electro-mechanical principles utilised are expected to be applied to a number of other gauging operations.

The new unit, shown in the accompanying photograph, consists of an electro-mechanical transducer, balancing circuits, oscillator, amplifier, computer and power supply. The transducer is a linear differential transformer which produces an electrical output proportional to the displacement of a separate movable core, to which a stylus is attached to provide rivet-head protrusion measurement. The balancing circuits are RC networks used for adjustment of a voltage to cancel the voltage produced by the transducer, and the oscillator is used as a signal source for the transducer transformer and balance circuits. The amplifier amplifies the differential voltage from the transducer and the balance circuits, the computer obtaining a signal from the transducer for computation of standard deviation. Automatic rivet handling and an improved computer now in the design stage are expected further to increase the time saving over present inspection procedures.

Miniature Cyclogram Recorder

A NEW miniature cyclogram recorder, the Elmes 12, manufactured by Elmes Staub & Co., of Richterswill, Switzerland, enables daily, weekly or monthly recordings to be made, and is provided with a switch which allows easy selection of the time period desired. The dimensions of the front frame are only $3\frac{1}{4} \times 3\frac{1}{4}$ in., and the apparatus is available either for panel mounting or locating in a portable housing. The instrument is claimed to be shockproof, and recording is made without ink, pen or ribbon.



A wide range of electrical quantities can be accurately recorded, and it can also be used for the recording of temperatures, speeds, viscosities, etc. Maintenance is said to be negligible as the graph is printed by a pressure dotting pin on a special paper, and no amplifiers or compensators are needed. Scanning of the measuring system takes place every six seconds, and there is said to be no paper friction or inertia of the point to introduce error. Each electrical value becomes instantly visible as printed and the entire recording period can be checked at a glance.

The instrument may be equipped with moving coil, cross coil, moving iron or ferrodynamic measuring systems. It has an accuracy of 2·5 per cent of full scale deviation, and an insulation resistance of 3 kV. Power for both the cyclogram discs and the internal mechanism for the pressure dotting pin is supplied by an a.c. synchronous motor of 110, 220, 240, 380, 400 or 500 volts, 50 or 60 c/s. The Elmes 12 recorder is stated to be suitable for operating in temperatures from −30 deg. C. to +80 deg. C.

New cyclograms can be quickly inserted and aligned and the complete records require a minimum of filing space. Consumption of all measuring systems is very low, with a minimum of 0·2 μW for the moving coil and 2 VA for the moving iron and ferrodynamic systems. The instrument is also available with adjustable rotating speeds for one, seven or thirty hours.

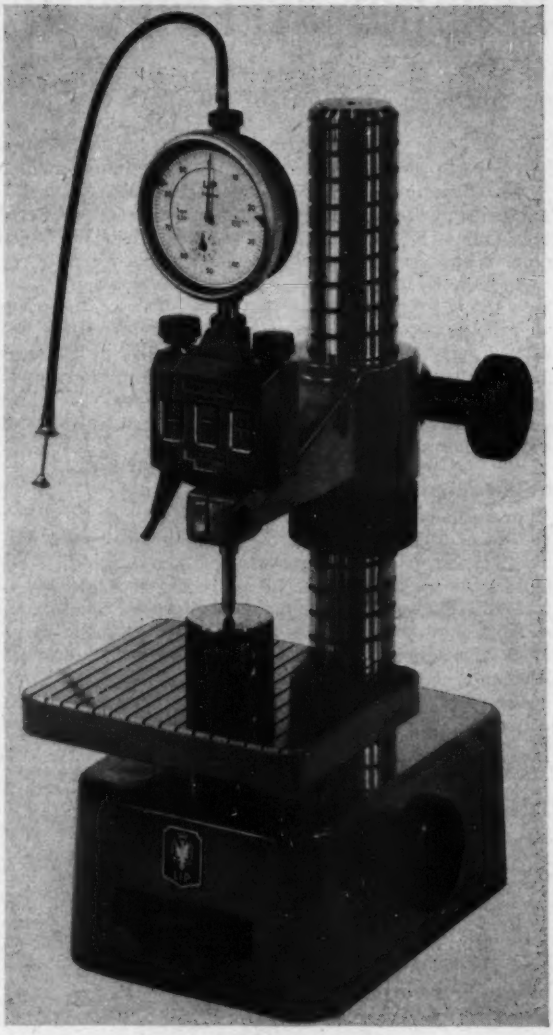
Visual Comparator for Measuring Components to ±0·0001 in.

A NOVEL electric comparator, originally developed by the French National Physical Laboratories in co-operation with Société Anonyme d' Horlogerie LIP, is an instrument of extraordinarily compact size weighing 6 oz. It is now available from Microtron Ltd. Operating direct from a plug-in connection to a light or power socket, it enables components to be easily inspected to close limits of accuracy, coloured lights in red, green and red indicating whether the component is undersize, within the specified limits or oversize. No auxiliary electrical equipment such as transformers, etc., is required, and the current consumption is said to be a few milliamperes.

The instrument has a light alloy body with a stainless-steel spindle of $\frac{1}{16}$ in. dia., and a choice of contact points is available for different voltages. Its three miniature neon lamps are claimed to have a long life and to be easily replaced when necessary.

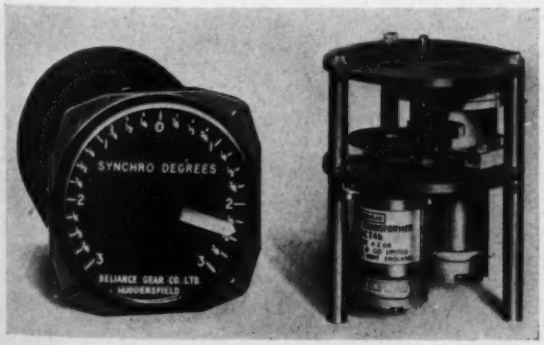
Setting up the comparator is a simple matter. The instrument is attached to the holder arm of a comparator stand. Calibration of the low limit is then carried out as follows. A slip gauge of the value corresponding to the required low limit value is placed under the plunger and the height is then adjusted so that the correct size (green) lights up. The exact adjustment is then obtained by turning the undersize (red) adjustment screw so that the correct size (green) symbol just disappears when the contact point touches the low limit gauge block. The high limit is adjusted by placing a gauge block corresponding to that limit on the stand table, and then turning the high limit adjustment screw until the correct size (green) just remains alight.

The unit can be used with a dial gauge in position if required, and a series of comparators can be set up for components having more than one size to be gauged. It is claimed that the measuring accuracy of the comparator makes possible the gauging of components with a tolerance of ±0·0001 in. of the nominal dimension, the sensitivity of transition from oversize to correct or correct to oversize being approximately 0·00001 in.



Modular Servo Gearbox

THE accompanying photograph shows a typical application, a remote servo indicator, of a modular system of servo gearboxes introduced by the Reliance Gear Co. Ltd., and is typical of the large number of different arrangements available within the standard design to suit individual specifications. The modular construction employs standard plates for mounting the rotating components. The basic module, which is corrosion-resistant throughout, is a gearbox conforming to DEF 5000, wherein up to seven shafts are mounted in ball bearings. These ball bearings are to ABEC 5 standards, friction tested to EL.1889, and are double shielded. The case is sealed against dust in a clean-air assembly shop.



Gear ratios are available to provide reductions up to 43,000,000:1 with precision gearing to Admiralty Class 1. There is accommodation within the standard module for up to six servo motors, potentiometers, synchros or other rotary components. Ratios and components are interchangeable for bread-board and prototype work, the shafts being extendable both sides at any intermediate pass. Torque-limiting slip clutches are available in all ratios and an eddy current drag damper may be fitted. Spring-loaded split gears for zero backlash in all ratios are also available, the gears being clamped to the shaft by a collet and split ring. Using solid gears the backlash on a 1:1 ratio is claimed to be fifteen minutes of arc only.

BENDING STRESSES IN NON-PRINCIPAL PLANES

by A. ORMEROD, B.Sc., D.I.C., A.M.I. Mech. E.*

IT is often useful to have available an alternative method of evaluating stresses. The following method of calculating the bending stresses in beams of angle section is offered as a variant on the more usual methods; it is very much quicker and clearer with a small sacrifice of accuracy.

As most of the standard angle sections are thin-walled, they can be represented by the centre-lines of their legs without serious loss of accuracy. The bending stress will vary linearly with distance in any particular direction so that the stress distribution can be sketched in terms of three unknowns—the stress at each of the corners. The three unknown stresses are evaluated from the three equations of static equilibrium.

Equal Angle Section

An equal angle section is represented in Fig. 1 (a); the dimension D is equal to the overall length of leg less half the thickness (t). The minor axis of the section is at 45 degrees to the horizontal. If a bending moment M_x is applied in the vertical plane the neutral axis will lie between the horizontal and the minor axis as indicated in Fig. 1 (b), which also shows the distribution of stress. To simplify calculation the stress distribution is re-defined in Fig. 1 (c).

Applying the three conditions of equilibrium to the section carrying the stresses shown in Fig. 1 (c), we have:

(a) $2Dt.\ f_G = \frac{1}{2}Dt\ f_c + \frac{1}{2}Dt\ f_A$

or $4\ f_G = f_c + f_A$

(b) Taking moments about AG,

$$f_G \frac{tD^2}{2} = f_c \frac{tD^2}{3}$$

i.e., $f_c = 1\frac{1}{2}\ f_G$

and from (a) $f_A = 2\frac{1}{2}\ f_G$

(c) Taking moments about G C,

$$f_A \frac{tD^2}{3} - f_G \frac{tD^2}{2} = M_x$$

$$f_G\ tD^2\left(\tfrac{5}{6} - \tfrac{1}{2}\right) = M_x$$

$$f_G = \frac{3}{tD^2} M_x$$

Summarising, the net stresses are:

at G, $f_G = \frac{3}{tD^2} M_x$ tension (1)

at C, stress $= \frac{1}{2}\ f_G$ compression (2)

at A, stress $= 1\frac{1}{2}\ f_G$ compression (3)

The stress distribution is shown in Fig. 1 (d) and it will be seen that the neutral axis slopes at $\tan^{-1}\frac{3}{5}$ to the horizontal.

The stress distribution for a moment M_y in the horizontal plane is shown in Fig. 1 (e), where $f_G = \frac{3}{tD^2} M_y$.

The stresses caused by a moment applied in any particular direction can be found by resolving the moment into components M_x and M_y and adding the stresses due to each of these components.

Unequal Angle Section

The same method is applied to the unequal angle section shown in Fig. 2 (a) with the stress distribution due to a moment M_x as indicated in Fig. 2 (b).

The three equations of equilibrium are:

(a) $f_G\ 2\ (B + D) = f_c\ B + f_A D$

(b) $f_G \frac{B^2}{2} = f_c \frac{B^2}{3}$ i.e., $f_c = 1\frac{1}{2}\ f_G$

and from (a) $f_A = f_G \frac{4D + B}{2D}$

(c) $f_A \frac{tD^2}{3} - f_G \frac{tD^2}{2} = M_x$

$$f_G \frac{tD^2}{6}\left(\frac{4D + B}{D} - 3\right) = M_x$$

$$f_G = \frac{6}{tD^2} \frac{D}{D + B} M_x$$

The net stresses are:

at G, $f_G = \frac{6}{tD^2} \cdot \frac{D}{D + B} M_x$ tension (4)

Stress at C $= \frac{1}{2}\ f_G$ compression (5)

Stress at A $= \frac{2D + B}{2D}\ f_G$ compression (6)

The stress distribution is shown in Fig. 2 (c); the neutral axis is at $\tan^{-1}\frac{3D^2}{B(4D + B)}$ to the horizontal.

The stress distribution for a moment M_y in the horizontal plane is shown in Fig. 2 (d), the stresses being:

at G, $f_G = \frac{6}{tB(B + D)} M_y$ tension (7)

Stress at C $= \frac{2B + D}{2B}\ f_G$ compression (8)

Stress at A $= \frac{1}{2}\ f_G$ compression (9)

The stresses caused by a moment in any other direction can be found by resolving the moment into its components M_x and M_y and adding the stresses due to each of these components.

Numerical Example

As an example of the use of the formulæ developed, the stresses set up in a beam B S U A 123, 9 × 4 × ¼ in., by a bending moment of 50 ton in. applied at 30 degrees to the vertical as shown in Fig. 3, are calculated.

In this case,

$B = 3\frac{1}{4}$ in. $\quad D = 8\frac{1}{4}$ in. $\quad t = \frac{1}{4}$ in.

$M_x = 43{\cdot}3$ ton in. $\quad M_y = 25$ ton in.

Stress at G

From formulæ (4) and (7):

$$f_G = \frac{6}{tD(D + B)} M_x + \frac{6}{tB(B + D)} M_y \text{ tension}$$

$$= \frac{6 \times 43{\cdot}3}{0{\cdot}5 \times 8{\cdot}75 \times 12{\cdot}5} + \frac{6 \times 25}{0{\cdot}5 \times 3{\cdot}75 \times 12{\cdot}5}$$

$$= 4{\cdot}75 + 6{\cdot}4$$

$$= 11{\cdot}1 \text{ t.s.i. tension.}$$

* Royal Military College of Science.

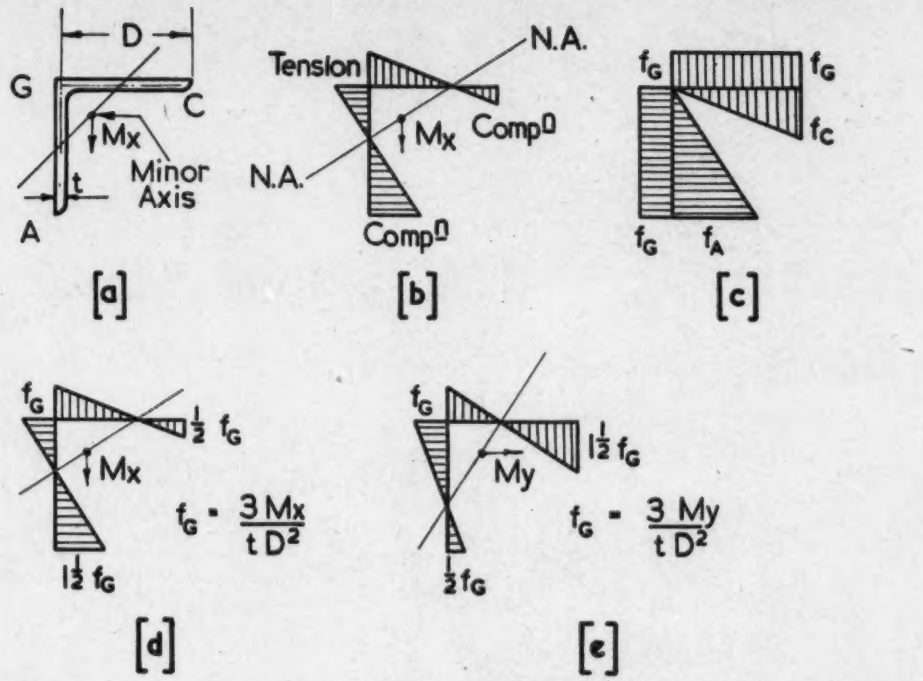


Fig. 1.

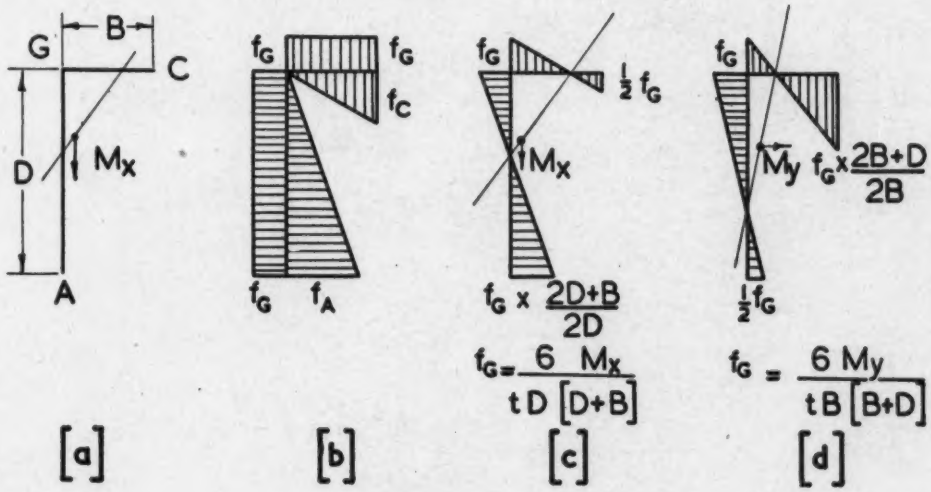


Fig. 2.

Stress at A

from formulæ (6) and (9):

Stress at A $= \left(4{\cdot}75 \times \frac{21{\cdot}25}{17{\cdot}5}\right) + (6{\cdot}4 \times 0{\cdot}5)$ compression

$= 9$ t.s.i. compression.

Stress at C

From formulæ (5) and (8):

Stress at C $= (4{\cdot}75 \times 0{\cdot}5) + \left(6{\cdot}4 \times \frac{16{\cdot}25}{7{\cdot}5}\right)$ compression

$= 16{\cdot}2$ t.s.i. compression.

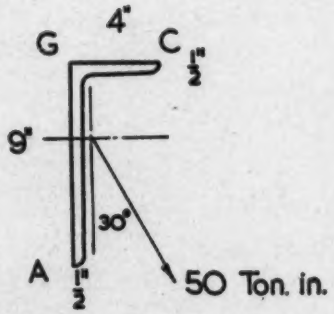


Fig. 3.

A FURTHER LOOK AT LEAF SPRING DESIGN

The design of leaf springs has not reached the state of perfection that its long history in engineering might suggest. This article indicates how calculation from first principles has improved on previous approximations

By W. P. YANESKE*

THE continued wide use of the leaf spring in modern vehicle suspension has encouraged a further examination of the conventional analytical basis on which springs are usually designed. The manufacturer has a distinct advantage in having the opportunity to compare the deflection properties of spring assemblies of great variety. Although these are simple and generally trouble-free, closer scrutiny during the application of load can indicate characteristics developing which would not be interpreted as desirable or intentional.

Fig. 1(a), for instance, indicates a shape which is not uncommonly seen when a spring is compressed to the condition of "zero" curvature, despite the unladen shape being that of an assembly of leaves of true radii. The shape is one naturally asserted. Fig. 1(b) represents developments in shape in an opposite direction. Regions of strength and weakness are self-evident in these two examples.

The local section of spring in Fig. 2 shows the tendency in some springs to develop gaps between the successive leaf steps; this is more obvious in the case of leaf ends which are neither speared nor drawn, although this same tendency can also be found in springs fabricated from leaves with drawn ends. The steps of the leaves are seen to be arched and with a concentrated contact of the leaf tip with the next upper leaf.

Outlined in Figs. 3(a) and 3(b) is a feature also to be encountered in spring manufacture, although it is not to be inferred that all springs suffer in this way. Fig. 3(a) shows the appearance of cambered well-fitting leaves in a spring as assembled before the usual scragging or test deflection is applied. After such test, Fig. 3(b) indicates a leaf-end which has "scragged off", an effect not to be attributed to inequality in heat treatment.

Fig. 1(a). Distortion of spring under compression.

Fig. 1(b). Alternative distortion sometimes seen.

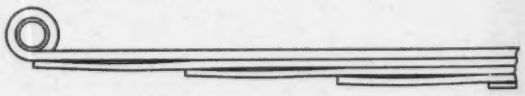


Fig. 2. Distortion in the form of gaps between successive leaf steps.

Fig. 3(a). Well-fitting leaves in a spring before scragging test.

Fig. 3(b). Deflected spring indicating a leaf end which has scragged off.

Requirements

These are then some general characteristics that occur in the course of manufacture; they are not necessarily peculiar to any one type of spring, although this is sometimes found to be the case.

A quite common requirement of springs in the laden state is that the shape, as generally following the pattern of the main leaf, shall be straight and not wavy, and with all

* *Technical Director, Toledo Woodhead Springs Ltd.*

supporting leaves bedding together throughout their length. The foregoing points indicate types of natural tendency developed under application of load, which can make the meeting of such requirements a difficult proposition.

But it is also obvious that such unevenness of individual and general assembled shape indicates regions of stress higher than anticipated in designing, while at the same time it must be acknowledged that such springs have the capacity to give satisfactory service. It would seem reasonable to consider designing nearer to these higher stress levels, provided that the stresses calculated could be uniformly achieved in practice. Such designing has the attraction of utilising a lower material content, allied to an expected reduction in cost.

Back to First Principles

Analytical investigation by Plint & Partners (consultants to Toledo Woodhead Springs Ltd.) has revealed that the conventional basis on which springs are usually designed is incomplete, and while it is adequate for the determination of deflection rate, actual checking by the use of strain gauges has shown that it affords only a general idea of stresses which are frequently taken care of by the use of a generous factor of safety.

The text-book theory of the multi-leaf spring is commonly illustrated by a spring of the type shown in Fig. 4; in theory, this is perfect, but in practice it cannot be realised, since it assumes an infinite concentration of load at the leaf tips. When conventional methods of design start from this text-book theory and include several empirical corrections to arrive at a practicable result. the procedure leads to a serious departure from the ideal of constant stress in the material of the spring; this is because, unfortunately, stress distribution between spring leaves is extremely sensitive to departures from the correct proportions.

For example, Fig. 5 shows the maximum bending stresses in a four-leaf spring having leaves of equal thickness, equal steps and no leaf tapering. Clearly, the lower leaves are too stiff, and the stress in the shortest leaf is 41 per cent higher than that in the longest main leaf. Methods of alleviating this by drawing the leaf ends in a more or less arbitrary fashion, by reducing the thickness of the shorter leaves or by introducing "nip" or "pull" between leaves, are expedients unlikely to result in a uniformly stressed spring, except by methods of rational analysis. Examples of such designs wasteful in material are numerous. Methods of rational analysis to avoid this were evolved years ago, but are lengthy to apply, and the implications of the analysis appear to be disregarded generally. It is the realisation of this which has prompted a re-examination of the problem, starting from first principles and with the idea of making a more efficient use of steel content within a spring.

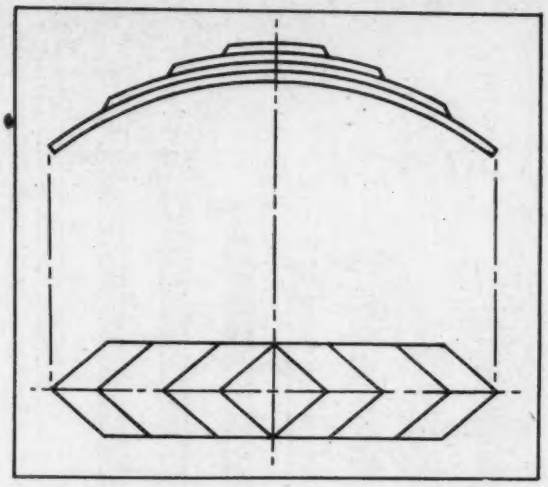


Fig. 4. Multi-leaf spring commonly illustrated in text-books.

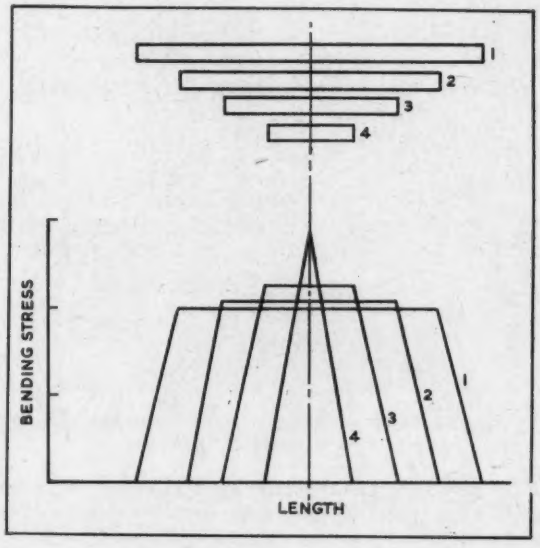


Fig. 5. Maximum bending stresses in a four-leaf spring.

Spring Efficiency

Since efficiency in spring design has not perhaps been given all the attention it deserves in the past, it would do no harm to define it briefly. If a bar of spring steel is bent, two things happen; energy is fed into the steel and stored in the form of strain, and the material is put into a state of stress, the stress varying through the thickness, being a maximum tensile stress at one surface and a maximum compressive stress at the other. For a bar of spring steel of any rectangular cross-section, bent until the maximum stress at the surface reaches a particular level, the energy stored in the spring per pound of steel contained in it is constant, irrespective of the shape or size of the spring cross-section. The amount of energy which can be stored depends only on the maximum stress that can be permitted, and increases very rapidly with this stress, in fact, by its square. Fig. 6 shows the relationship between the maximum stress and the energy which can be stored in 1 lb. of steel. For a stress of 50,000 p.s.i., the amount of energy stored in 1 lb. of steel is only 4·1 ft.-lb. If the maximum stress is increased to 70,000 p.s.i., the energy increases to 8 ft.-lb. and with the maximum stress increased to 80,000 p.s.i. the energy storage is further increased to 10·5 ft.-lb. per pound of steel.

Basically, the spring designer requires to produce a spring having a given rate and capable of carrying a given load. Another way of saying this is that he requires to design a spring which will absorb a given amount of energy, since the product of the mean load and the deflection gives the energy stored in the spring at its working condition. Knowing the energy required to be absorbed and having decided upon a permissible maximum stress, he can immediately determine the theoretical minimum amount of steel necessary to make the spring. For example, if the spring has to absorb 100 ft.-lb. of energy at the working-load, and if the permissible working stress is such that 1 lb. of steel can absorb 10 ft.-lb. of energy, then clearly it should be theoretically possible to design a spring for the duty weighing 10 lb. only.

All this, of course, is not new, for it is always the objective of designers to produce springs in which as much as possible

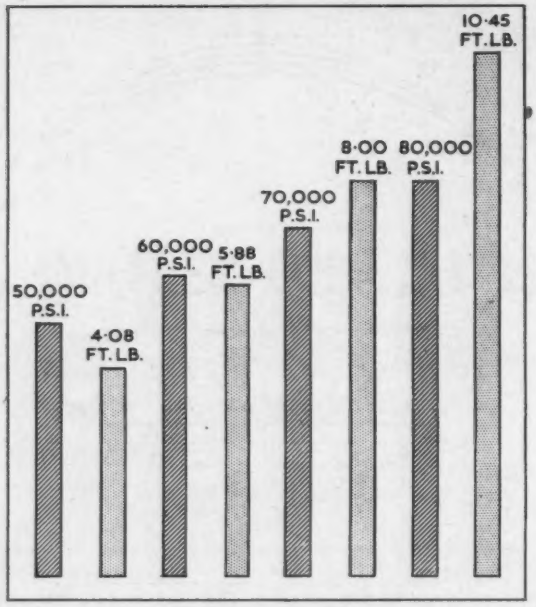


Fig. 6. Relationship between maximum stress and the energy stored in 1 lb. steel.

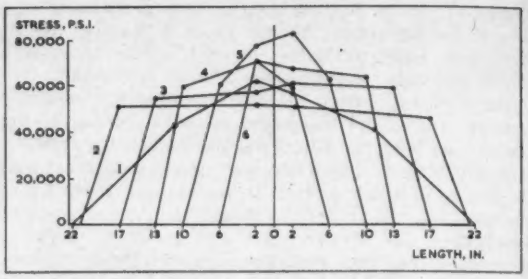


Fig. 8(a). Maximum stresses in conventional six-leaf spring.

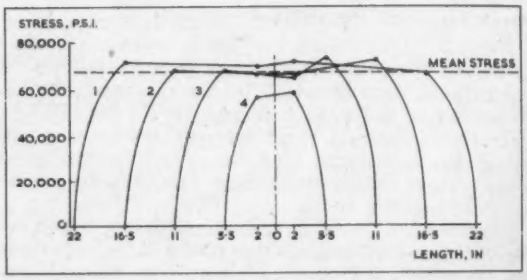


Fig. 8(b). Maximum stresses in redesigned four-leaf spring.

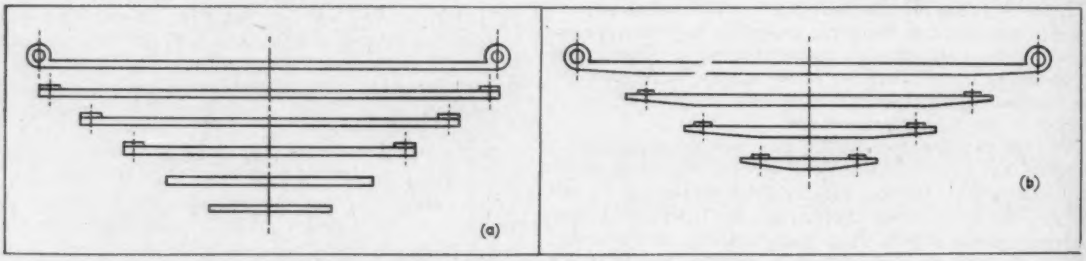


Fig. 7. A six-leaf conventional spring compared with a four-leaf redesigned spring for equivalent duty.

of the steel content is stressed to the same chosen maximum level. What should be more fully appreciated is the effect of this requirement on the weight, and hence the cost, of a spring.

Thus it will be seen that a spring weighing 10 lb. and stressed uniformly to 80,000 p.s.i. maximum could absorb 105 ft.-lb. of energy. If, however, due to imperfect design, one half of the spring were only stressed to 50,000 p.s.i., then the weight of the spring would be increased to no less than 14½ lb. The 4½ lb. of extra steel would serve no useful purpose, being merely the result of approximation in design. In the first case all the steel in the spring was stressed to the design level, and the efficiency of the spring was virtually 100 per cent. In the second case, where 14½ lb. of steel do a job which could be done by 10 lb., the spring efficiency is the ratio of 14½ to 10, about 70 per cent.

Practical Design

It is, of course, not possible to produce an actual leaf spring with an efficiency of 100 per cent, due to various necessary inactive regions (for instance, at the eyes and at regions such as at the leaf tips which are inevitably stressed to less than design level). However, it is possible to design a spring in such a manner that a very large part of it is stressed uniformly to the design figure, and it is just the defect of the general methods of traditional design that this objective is not achieved with any certainty.

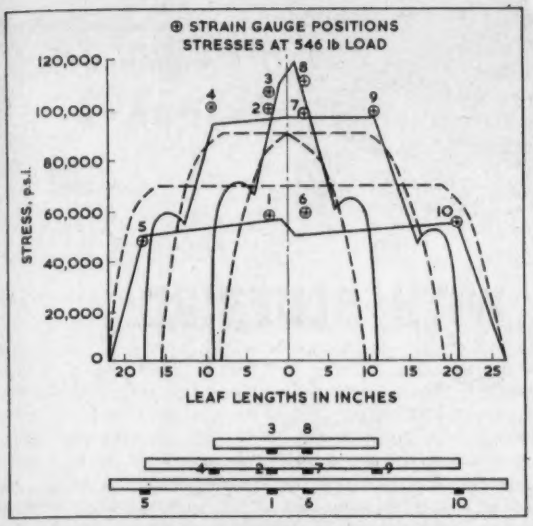
The principal claim for an "ideal" spring is that more refined methods of design can result in a closer approach to the ideal of constant stress level throughout the spring. This does not overlook special requirements, such as reduced stresses in the main leaf. The point is that by such rational method of design it is possible to know what these stresses really are, and thereby achieve more efficient and lighter springs.

Springs of such design have been made for comparison with their conventional counterparts, and fitted with strain gauges at suitable critical points for the purpose of obtaining factual readings. By the use of Young's Modulus, the ratio between strain and the accompanying stress, known for steel, strain readings may be directly converted into stresses.

Fig. 7(a) shows a six-leaf conventional production type spring weighing 23 lb. 5 oz., where as Fig. 7(b) indicates a four-leaf spring for the equivalent duty weighing 16 lb. 4 oz. Fig. 8 shows the comparison of the actual measured stresses suitably charted. The maximum measured stress in the six-leaf spring is 83,000 p.s.i., as compared with 74,000 p.s.i. in the lighter four-leaf spring.

Fig. 9(a) gives similar relevant details checked on a production type three-leaf spring, while Fig. 9(b) supplies comparable data for an equivalent two-leaf spring. The weights are 17 lb. and 12 lb. 11 oz. respectively.

This is a particularly interesting comparison. Figs. 10 and 11 show the shape of the two-leaf spring in the free position



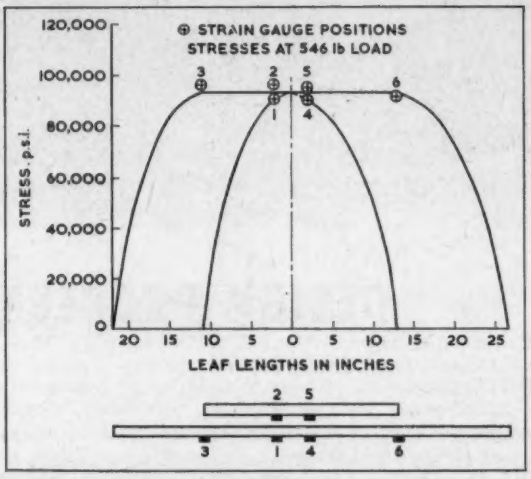


Fig. 9(a) (left). Stresses in three-leaf conventional spring.
Fig. 9(b) (above). Stresses in two-leaf equivalent spring.

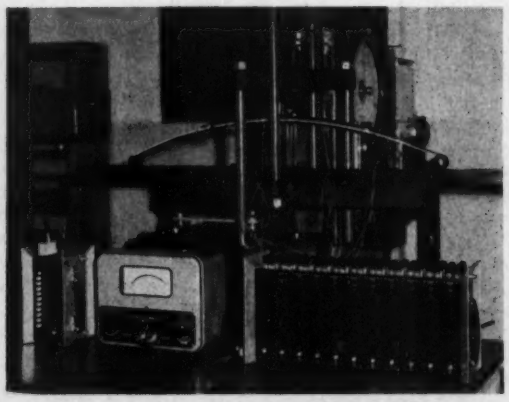


Fig. 10. General view of testing machine with strain gauges in position on a two-leaf spring, showing the measuring and recording instruments.

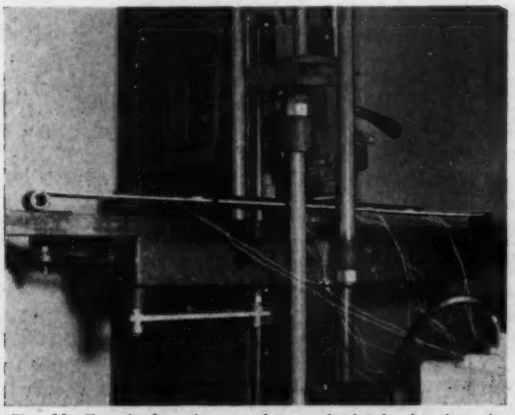


Fig. 11. Two-leaf springs under static load, showing the shape of the spring and the strain gauges connected to record the strain at various points.

and when compressed to zero curvature, and indicate a particularly good shape. It becomes increasingly difficult to achieve a really good spring shape in conjunction with really uniform stress distribution as the number of leaves in a spring is reduced. The tapered character of the two-leaf spring based on these principles of design goes far towards achieving these characteristics, and it should be added that the two-leaf conversion fulfilled its functions successfully in actual practice.

As regards stresses, the highest measured stress in the three-leaf spring was 110,000 p.s.i. at strain gauge 8, compared with 96,000 p.s.i. in the two-leaf spring at strain gauge 3. The measured values of stress confirm the calculated ones within quite close limits allowing for manufacturing tolerances in the springs, and a 5 per cent tolerance on the readings from the strain gauges which precludes expectation of exact agreement.

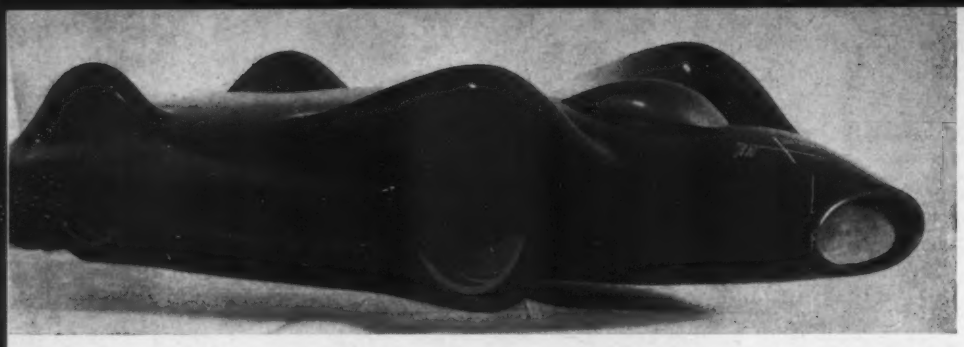
From these results it will be noticed that in the case of the two-leaf spring the stress in the main leaf is on the same level as the second leaf, whereas the main leaf of the original three-leaf spring is stressed much lower. The fact remains that the two-leaf spring with a main leaf stress of 91,000 p.s.i. stood up to service tests, and supports the view that, provided the higher stress levels are smoothed out, a fairly high stress level in the main leaf can be adopted.

However, it is possible to design a three-leaf spring with a lower level of stress at 70,000 p.s.i. in the main leaf and 90,000 p.s.i. in the second and third leaves, as indicated by the dotted line in Fig. 9(a). This design would weigh 15¼ lb. (1¼ lb. less than the original) and in accordance with the principles of correct design the maximum stress at any point should be only 90,000 p.s.i. as compared with 110,000 p.s.i. at strain gauge 8 in the original spring.

Existing methods of spring design can include many empirical factors, including points where the designer must base on judgment by experience. On completion, it is unlikely that the actual stresses in such an empirically designed spring will have the close relationship and uniformity intended; this is borne out in the course of strain gauge tests, when again and again unsuspected localities of high stress can be found in springs of conventional design.

By using a rational basis of design, with its refinements of correctly proportioned leaf-end tapers, the inequalities of stress can be largely avoided, making the fullest use of the steel content for the stress level selected. Where the number of leaves and the length of leaf steps result in the desirability to taper the main leaf overhang, this taper can be provided, with the option of maintaining the original steel section for the greatest strength of the usual rolled eye.

Students of leaf spring design may be interested to consult the Manual on Design and Application of Leaf Springs, *published by the Society of Automotive Engineers Inc., 485 Lexington Avenue, New York, 17, N.Y.*



Wind tunnel model of Bluebird, showing the final design—note the absence of fins.

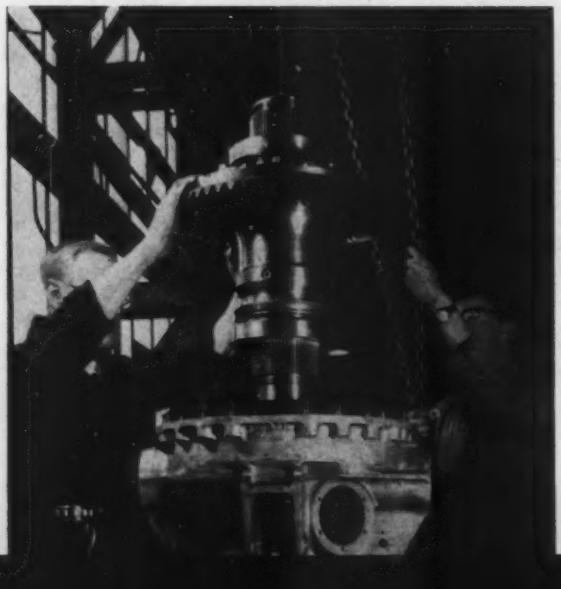
DESIGN PROBLEMS WITH BLUEBIRD

FIVE painstaking years have gone into the design and building of the new Bluebird with which Donald Campbell will attack the world land speed record in September. While the knowledge and experience gained are expected ultimately to benefit the automobile industry and others engaged in engineering design, many of the immediate problems have involved designing into the unknown. The finished car will weigh 8,000 lb. and will be driven by a Bristol-Siddeley Proteus free turbine engine capable of giving over 4,000 h.p., resulting in almost unprecedented power to weight ratio of ½ b.h.p. per lb. An essential consideration in the design was to achieve maximum strength with minimum weight, and the frame was constructed from light alloy foil formed into a honeycomb sandwich ¾ in. thick and faced with alloy sheeting.

There is no clutch or conventional gearbox, but power is transmitted by the gas stream between primary and power turbines, and the latter is directly connected through reduction gears to the drive shafts connected to the four wheels of the car. In operation the engine will be started and run up to a predetermined compressor speed with the car locked on the brakes. When this point is reached the brakes will be released and the car will accelerate at a rapid but controlled rate to maximum speed. This mode of operation imposes a tremendous loading on the driving gears, which will have to withstand up to 4,500 lb. per in. of gear face-width at standstill. Even during the run a load of 3,400 lb. is expected, and under these conditions additional hazards are the high rotating speeds (14,000 ft. per min. or 160 m.p.h.) which make it difficult to apply adequate lubrication, and close proximity of the inboard mounted brake discs which are expected to reach a temperature of over 900 deg. C. during the braking period. An adequate supply of lubricant to the gears and bearings is essential, not only for lubrication purposes but also for cooling. In order to stop the car in the 7 miles available, air brakes are first used down to 400 m.p.h., and then disc brakes are applied. To stop from 400 m.p.h. involves dissipation of energy at the rate of 75 million ft. lb. in 60 sec., because of limitations of weight, the calipers which carry the linings are made of magnesium alloy. There are two calipers each consisting of three pairs of brake linings acting on each side of the rotating discs, making twenty-four pairs of linings in all. The discs are keyed into the driving hubs so that they can slide along towards the fixed linings as wear takes place. The brakes are power operated with compressed air from 3,000 p.s.i. storage cylinders, the circuit being duplicated for safety reasons. The friction material is a development of that used on the Meteor jet fighter and is moulded from asbestos fibres, synthetic resins and metallic powders blended with friction additives. An unusual feature of the pad is the incorporation of a metal reinforcement at the back during the moulding process.

A freewheel system is incorporated in the front drive shaft, which is in effect a Renolds sprag clutch. This is needed because, on deceleration, forward redistribution of the car's weight takes place and decreases the radius of the front wheels. This results in the front wheels rotating faster than the rear wheels, and as a four-wheel drive system is used there is danger to the half-shafts unless a freewheel is incorporated. The experience gained with this four-wheel-drive system at very high speeds will be most valuable to designers of vehicles having this type of drive in commercial and military fields.

Assembling one of the two spiral bevel reduction gear units designed and built by David Brown Automobile Gear Division.



The Dunlop high-speed tyre-testing machine, showing readings being taken on a load gauge during calibration.

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Tooth Profile Hardening

Successful application in industrial practice is now claimed for a Russian patent which covers bulk induction heating of gear teeth made of a specially developed, low hardenability steel, in order to achieve surface hardness while retaining a ductile metal core. Features of the process include induction heating of the teeth in depth, and the choice and rate of application of quenching medium to the tooth surface. This rate should either equal or slightly exceed the critical, in order that the rate of cooling in the core of the tooth remains significantly below the critical point. A similar effect has been achieved by a twin-frequency induction heating procedure associated with a more expensive installation and preliminary heat treatment.

The aim is the achievement of a surface hardness in the range of 56-62 Rockwell C and a core hardness not exceeding 45 Rockwell C. Because medium carbon steels (0·5 per cent) harden right through, and most alloy steels were developed to increase hardenability, new avenues were needed in order to produce a steel even lower in hardenability than medium carbon steel. Experiments carried out at the experimental plant of the Central Ferrous Metallurgy Research Institute in Russia resulted in the production of special low hardenability steels, all containing about 0·5 per cent C, 0·2 per cent Si and 0·05 per cent Cr; the steels differed in manganese (0·13-0·45 per cent), nickel (0·15-0·30 per cent) and titanium (0·11-0·28 per cent).

Tests have shown that with a special method of diffusion de-oxidation by a boron calcium preparation containing aluminium powder, a limitation of manganese below 0·15 per cent and of nickel below 0·30 per cent is sufficient to achieve a reduced hardenability, but the addition of 0·1 per cent titanium to bind the sulphur is essential in order to retain satisfactory forging properties. Vanadium can be substituted for titanium to ensure small austenite grain size.

In the course of the experimental developments, the hardenability criteria were determined by the standard and quench tests of cylindrical specimens, and of simulated gear tooth specimens. The hard case of 56-60 Rockwell C extended all over the tooth profile to a depth of 1 mm, and across the tooth tip to a depth of 2 mm. At twice that depth the Rockwell hardness was about 30-35 C, which corresponds to an impact value exceeding 213·0 p.s.i.

Pyrographite

In recent years considerable work has been done at the Royal Aircraft Establishment on the deposition of carbon at high temperatures, but the first commercial means for producing quantities of shapes and parts from deposited carbon has been developed by the Raytheon Co. in the U.S.A. Major research is now being devoted to studying the structure of Pyrographite, the mechanism by which it is formed, and its properties under various conditions.

Pyrographite is a polycrystalline form of graphite deposited from a carbonaceous vapour on to a suitable substrate at temperatures above 2,000 deg. C. It is a dense material completely impervious to gases and liquids, is much stronger than commercial graphite, and exhibits a greater degree of anisotropy in its thermal and electrical properties than single crystal graphite. It also displays an unusual degree of preferred orientation.

Most significant of the mechanical properties are its strength and resistance to erosion; in strength, it surpasses stainless steel, particularly at temperatures above 2,000 deg. C. It is possible to produce commercial shapes to close tolerances without extensive machining, but where this is necessary it may be ground or cut by using ultrasonic techniques, or with diamond or carbide wheels. This material is likely to find extensive application in the atomic energy field, for rockets and missiles, and for the leading edges of high-speed aircraft where the full advantage of its properties at high temperatures may be utilised.

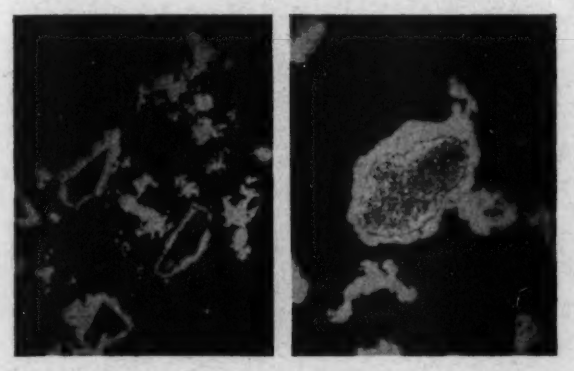
Composite Powders

The basic process employed by Sherritt Gordon Mines Ltd., Canada, to produce high-purity nickel powders can be used with some modification to deposit nickel or cobalt on the surfaces of various other fine powders. A wide variety of both metallic and non-metallic powders can be treated in this way, and the accompanying micro-photograph shows the core and coating.

These composite powders may find applications in controlled expansion (thermostats), electrical resistance and magnetic alloys. There is also the possibility of coating highly reactive metals such as aluminium or chromium with nickel, which is less reactive—the welding rod and brazing compound industries may find these products of interest. With metal/non-metal composites, carbides and borides coated with nickel or cobalt may find a use in the manufacture of tool bits.

Metals which have been coated on a pilot production scale include iron, copper, chromium and aluminium, and experiments are being currently carried out with cobalt, molybdenum, titanium, tungsten and silver. Non-metals such as tungsten carbides and aluminium and chromium oxides are in pilot production, and experimental work includes graphite and oxides of titanium, zirconium and vanadium. Core materials ranging in size from one micron to 100 mesh have been successfully coated.

Microphotographs of (left) a silicon carbide powder particle, and (right) an aluminium particle, both coated with nickel.



Application of Insulating Varnish

To apply insulating enamel or varnish to copper and aluminium wire, complicated technological processes must be employed with the use of expensive equipment, including resistance furnaces for drying the insulation. These use a large amount of power, and there is no assurance of a high-quality product when drying is done by this method. The solvent, evaporating during drying, must pass through the varnish film, with the result that the latter becomes porous, thus lowering the dielectric strength of the insulation.

At the Enamel Department of the Moscow Cable Plant there is in operation an experimental plant which operates on a new method based on the induction principle. In this, the coated wire is heated by passing it between two copper tubes (inductors) through which flows high-frequency current. By controlling the strength and frequency of the current, the wire may be heated to any desired temperature. The design of the installation is such that the moving wire can be observed and stopped at any moment; this was not possible in previous installations because the varnish or enamel film was liable to over-heat.

The quality of the product is greatly improved by the new method of drying, because the heat is supplied to the film from inside, i.e., it flows outwardly in a radial direction from the heated conductor. For this reason the solvent evaporates without having to pass through any barrier, and thus no pores develop in the coating. It has been established that the dielectric strength of the insulating coating is increased by a factor of one and a half when the new method is applied, and there is also a considerable economy in operation.

Scale Prevention

North American Aviation Inc. have developed a new coating which prevents scale formation on metal during heat treatment and will permit faster and cheaper heat treatment of metals including stainless steel, nickel-chrome alloys, cobalt alloys, copper alloys and the new exotic alloys now under develoment.

The new scale preventative, which is known as Skalix, adheres to the metal at furnace temperatures, forming an oxygen-tight seal, and can be applied by spraying or dipping. As the metal cools and contracts, the coating peels off by itself and in many cases no further processing is necessary. Previously, the best procedure for heat-treating metal without scale formation was by the use of inert gas atmospheres in special furnaces, which is an expensive method necessitating a large outlay of capital and thereby causing an increase in the price of parts.

The new coating is relatively inexpensive and a gallon will cover approximately 1,500 sq. ft. of metal surface.

Three test plates coated with Skalix, after treatment in an oxidising atmosphere.

Glass Fibre Reinforced Polyester Plastics

Recent investigations by a German laboratory show that the durability and resistance of polyester plastics products reinforced with glass fibre or glass fabrics is governed less by the nature of the glass material and its chemical composition than by the surface finish of the fibres. Thus, given the correct procedure, manufacturers can improve the quality of their products while retaining a wide margin of freedom in the selection of the glass. Tests proved that the chemical composition of the glass fibres was not a determining factor and that a low-alkali glass is not an essential requirement, glass with a 12-14 per cent alkali-oxide content being safely used.

It was found that the essential requirement of a suitable surface can be obtained by the use of sizing agents. Weathering tests on different types of plastics, where the reinforcing fibres had been treated with various finishes, yielded fairly consistent results, confirming the importance of finishes to obtain ultimate strength and impact toughness.

Plastic Protection for Bolts

Corrugated roofing sheets are generally screwed to timber structures or hooked on to metal members, the holes being sealed by means of zinc or bitumen washers. As a result of weather action, the washers become corroded and/or give rise to dark stains and streaks on the sheets. Efficient protection can be provided by plastic cap and washer sets in which the washer is placed over the hole, and, after screwing is completed, the plastic cap pressed over the screw head and pushed home against the washer. It is claimed by the Dutch manufacturers that these corrosion-resistant caps and washers ensure permanent protection against the weather. Similar fittings are made in the U.K. by the Dowty Group.

Refractories for Glass Melting

The strength of the bond in alumino-silicate refractories depends on the degree of conversion of the raw clay to the stable mullite which is, in turn, affected by several factors.

In the development of a technology for the production of high alumina blocks for use in glass tanks, a new method of making dense, homogeneous structures of mullite-bonded refractories is reported from the U.S.S.R. With these products, glass penetration is much less than with the old-type coarse-grained structures, and it is stated that a solution of the glass phase of the refractory by the molten glass does not lead to a breaking away of grog or mullite, and, consequently, erosion of the refractory proceeds at a uniform rate.

Grain size and the intimate contact of the particles are considered to play a vital role in the production of this type of dense refractory. The firing operation of the pressed shapes was carried out in reducing conditions, an unusual factor in industrial production of alumino-silicate. The large differences between true and apparent porosities indicate that the majority of the pores were sealed, presumably by the mullite bond.

Petrographical investigation showed that the refractory prepared by the new method had a better structure than materials made by orthodox techniques. The most important fact from the study is that, as distinct from electrically fused mullite, the glass phase of the unreacted grog in the test material was in the form of separate inclusions and located inside the skeleton growth of mullite needles, i.e., the grog was completely and protectively surrounded by mullite. There was a certain amount of mullitisation on the grog particles themselves, but this was small compared with that in the bond.

These studies confirm the possibility of obtaining satisfactory mullite bonded refractories from ordinary grog and technical grade alumina. Subsequent plant trials showed these refractory bricks to be greatly superior in resisting glass attack, to bricks made from electrofused mullite.

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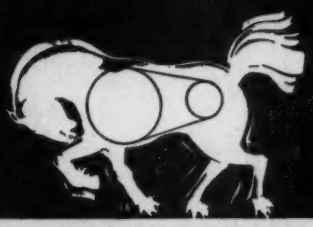

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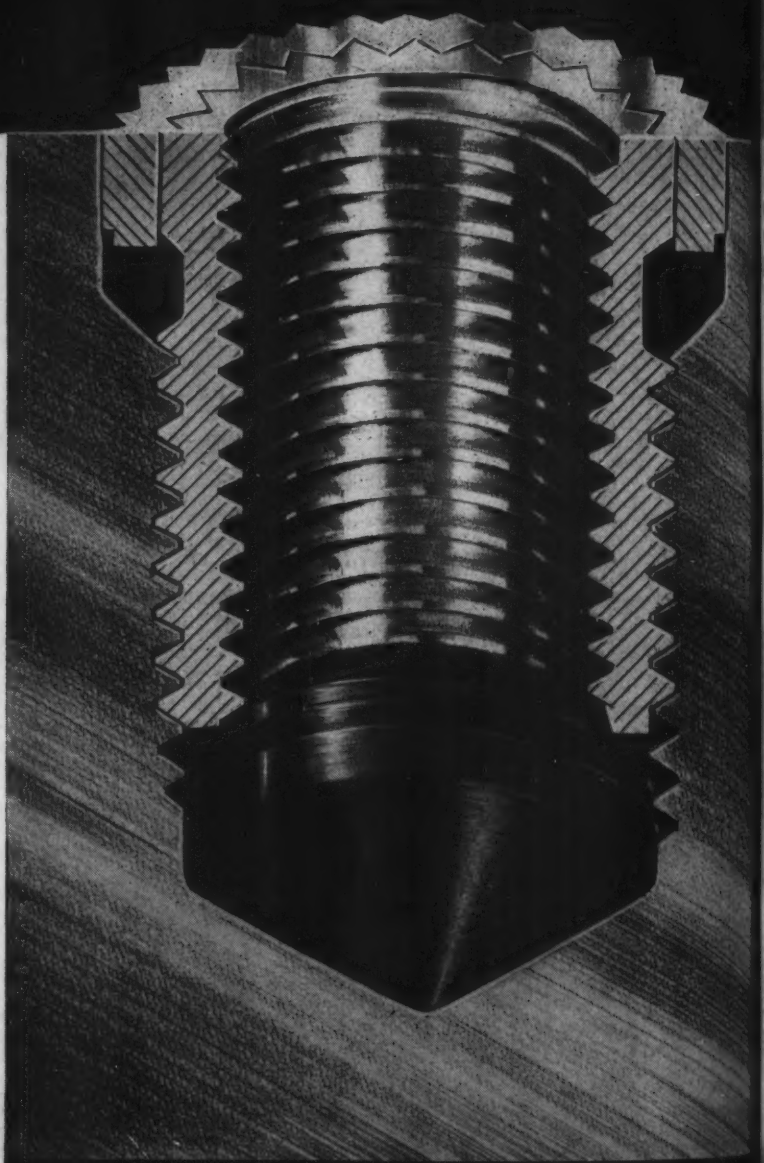

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THERMAL INSULATION

Engineering Materials and Design

DATA SHEET No. 42

The examples below indicate heat gradients in walls after a steady state has been reached.

$$\frac{\text{Resistance R}}{\text{(B.t.u./hr./sq. ft./°F.)}} = \frac{L}{k} = \frac{1}{C}$$

where L = thickness of material (in.);
k = thermal conductivity (B.t.u./hr./sq. ft./°F.)

$= \frac{t_1 + t_2}{2}$, where t_1 and t_2 are the temperatures of the two surfaces, and

C = conductance (B.t.u./hr./sq. ft./°F.) (for air approximates to 1·0).

Typical values of k (for precise values, reference should be made to specific manufacturers) are given below:

4½-in. brick	...	...	...	...	...	...	k =	8·0
½-in. plaster	...	...	...	...	...	...		4·0
½-in. plaster board	...	...	...	...	...	...		1·1
½-in. fibre board	...	...	...	...	...	...		0·32
¼-in. hardboard	...	...	...	...	...	...		0·26
⅜-in. plywood	...	...	...	...	...	...		0·96
2½-in. grade A slag wool	...	...	...	...	...	...		6·66
3½-in. grade A slag wool	...	...	...	...	...	...		11·66
1/16-in. iron sheet	...	...	...	...	...	...		360·0

The inner and outer air resistance values are based on combined convection and radiation coefficients, and approximate to 0·7 for the inner surface and 0·3 for the outer surface.

In example (5):

Resistance of inner surface	=	... ...	0·7
„ „ ⅜-in. plywood	= L/k = 0·1875/0·96 = 0·195, say		0·2
„ „ 3-in. air space	= 1/C = 1/1 =	... ...	1·0
„ „ 1/16-in. iron sheet	= L/k = 0·0625/360 = 0·000174, say		0
„ „ outer surface	=	... ...	0·3
		Total Resistance (R)	2·2

$$U = \frac{1}{R} = \frac{1}{2{\cdot}2} = 0{\cdot}45 \text{ (B.t.u./hr./sq. ft./°F.)}$$

where U = thermal transmittance.

Combined inner and outer air surface resistances equal a closed air space in insulating value, i.e., closed air space value = 1·0. Inner + outer surface resistances = 0·7 + 0·3 = 1·0. These resistances are important with sheeting having values of k exceeding 2, but relatively unimportant with good insulating materials.

Iron sheet 1/16-in. thick with value = 360 has a resistance of 0·000174. The heat resistance of any thin sheet where k exceeds 2 is too small to affect insulation unless combined with an air space.

R_s = Resistance of inner surface. R = Total resistance.
R_1 = Resistance of first material.
R_2 = Resistance of second material.

Temperature drop through surface air film = $\frac{R_s}{R}$ × temperature difference between inside and outside.

Temperature drop through first material = $\frac{R_1}{R - R_1}$ × temperature difference between first surface and outside.

Temperature drop through second material = $\frac{R_2}{R - (\text{surface } R_2 + R_1)}$ × temperature difference between second surface and outside.

In example (1):

Temperature of inner surface of wall =

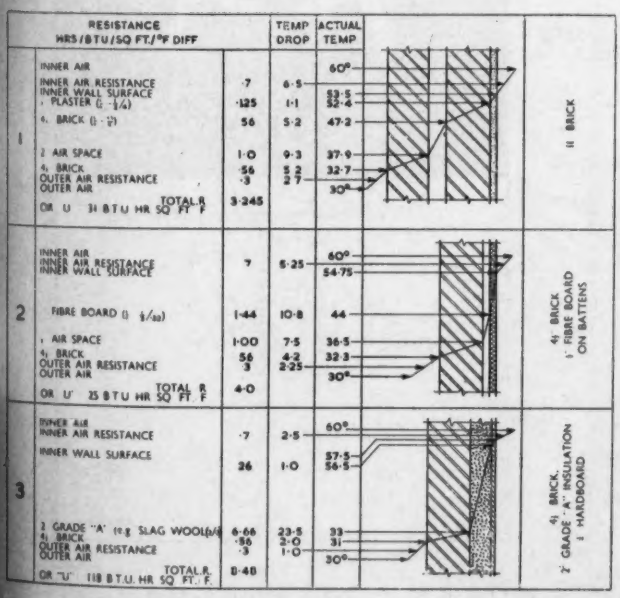
$\frac{0{\cdot}7}{3{\cdot}245} \times (60° - 30°) = 6{\cdot}45$ (say 6·5)

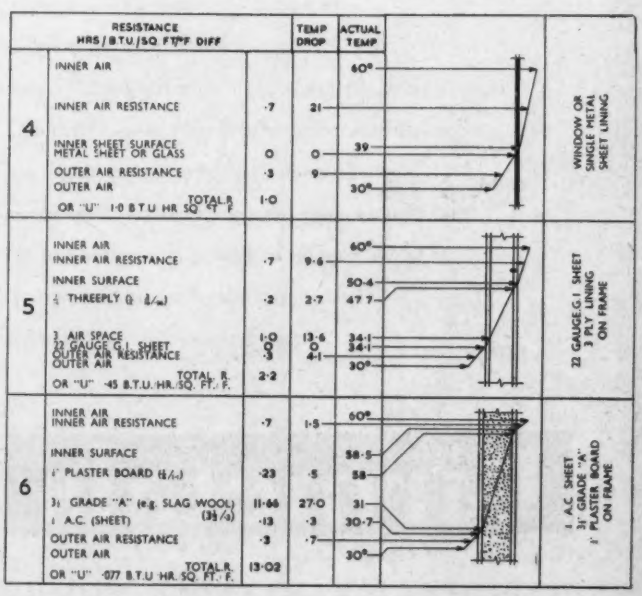
∴ 60° − 6·5° = 53·5°F. inner surface temperature.

Further: 3·245 − 0·700 = 2·545

$\frac{0{\cdot}125}{2{\cdot}545} \times (53{\cdot}5 - 30) = 1{\cdot}1$ and, 53·5° − 1·1° = 52·4°F. second surface temperature.

Data by S. Roberts, A.M.I.E.D.





EMD 3313 for further information

the designer and the doodle

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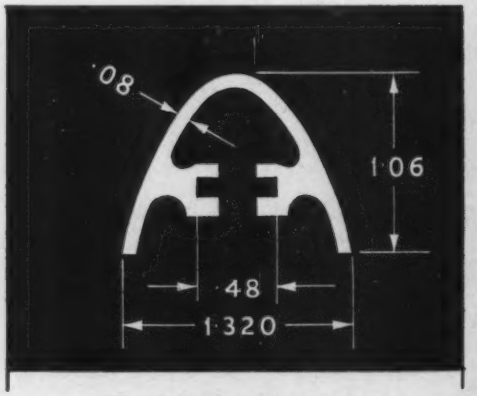

Sketch dimensioned section here

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RIVET SIZES AND STRENGTHS

Engineering Materials and Design
DATA SHEET No. 43

This combined nomogram can be used for most problems involving calculation of rivet size for a given strength requirement and rivet shear strength. Symbols used are:

D = rivet diameter (in.);
T = sheet or plate thickness (in.);
Fb = maximum bearing stress of rivet material (p.s.i.);
Fs = maximum shear stress of rivet material (p.s.i.).

Shear strength (centre scale) is in lb.

Solutions for shear strength of rivets are obtained from scales 1, 3 and 5, using the *left-hand* scale figures on scale 5.

Example 1. Given a $\frac{3}{16}$-in. diameter high-tensile steel rivet in single shear, to find the shear strength of the rivet. Fs for high-tensile steel is taken as 74,000 p.s.i. Connect this value of Fs to rivet diameter on scale 1 and read off answer for SINGLE on the centre scale; i.e., 2,000 lb.

In the case of rivets in *double shear*, it is theoretically correct to calculate the shear strength as *twice* that for single shear. However, in practice, resistance to shear is not always doubled when the rivets are in double shear, and the slightly lower values given by the DOUBLE scale on the right-hand side of scale 3 may be preferred as safe figures. Thus, in the example calculated, if the rivet were in double shear, the shear strength is given as 3,600 lb., rather than $2 \times 2{,}000 = 4{,}000$ lb.

Calculation of rivet diameter: Scales 1, 3 and 5 may be used, as above, for finding the rivet diameter associated with a required shear strength and selected value of Fs. Alternatively, scales 1 and 5 and 2 and 4 can be used in pairs to arrive at a rivet diameter consistent with equal rivet shear and bearing strengths. In this instance the centre scale (3) is used *as a reference line only*.

Example 2. To find the optimum rivet diameter for an aluminium alloy rivet (Fs = 35,000 p.s.i.) in $\frac{1}{4}$-in. alloy sheet (Fb = 70,000 p.s.i.), the rivets being in single shear. *First* connect corresponding T and Fb values on scales 2 and 4 respectively. *Second*, through the same point on scale 3, project from the Fs value read *on the right-hand side* of scale 5 through the same point established on scale 3 to the diameter scale 1. Read off rivet diameter required = 0·316 in.

For rivets in double shear, the required rivet diameter may be halved (theoretical value), or taken as 0·6 of the single shear size (safe practical value).

Special Note on Simplified Empirical Formulæ

The allowable bearing stress in a material is approximately equal to twice the allowable shear stress, this figure commonly being adopted for rapid solutions. When the rivet and sheet or plate are in the same material, the following simplified formulæ apply:

Rivets in single shear:
diameter = 2·54 × plate or sheet thickness.
Rivets in double shear:
diameter = 1·27 × plate or sheet thickness.

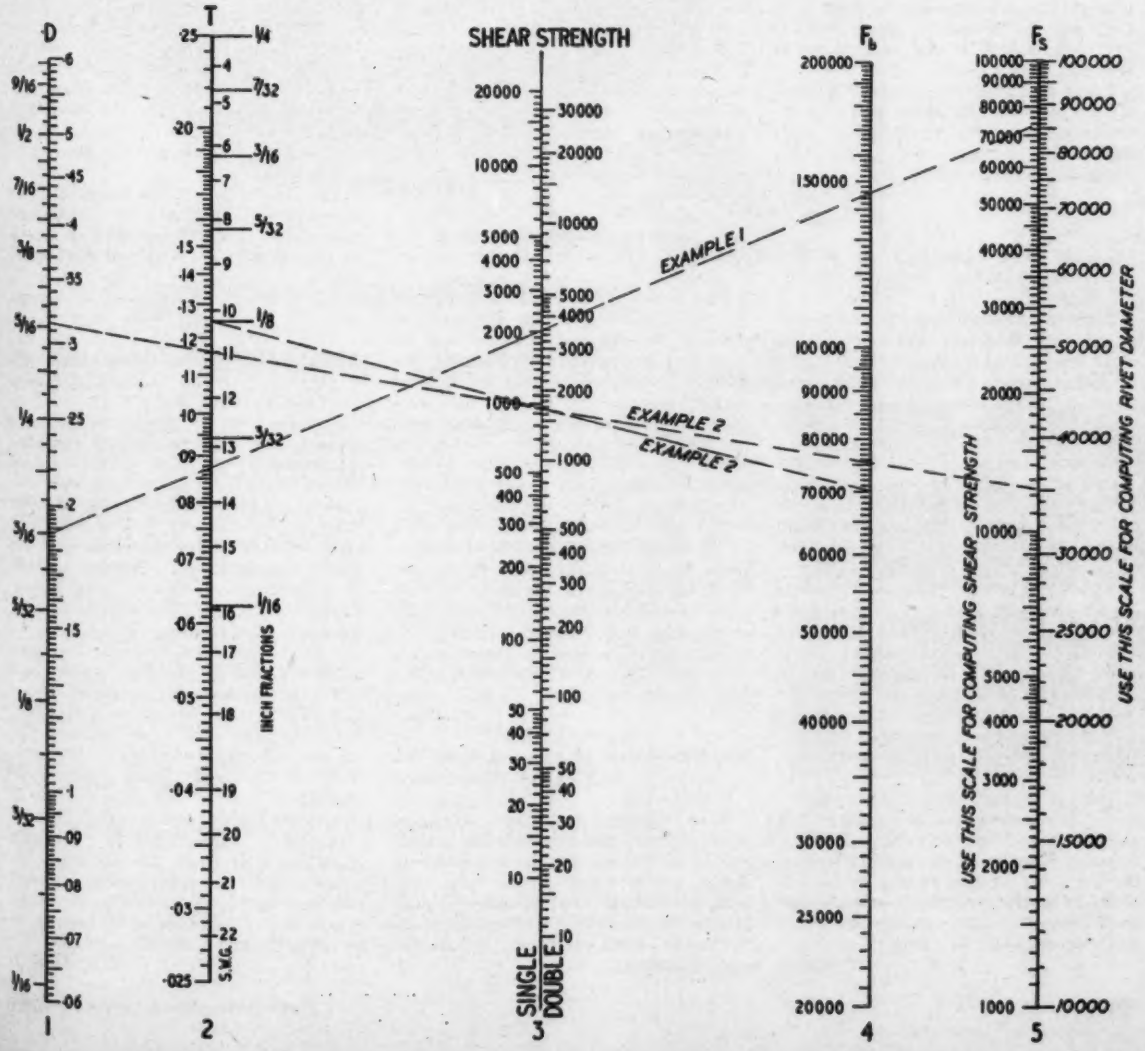
These formulæ, however, have definite limitations for thicker plates and large rivets, tending to give excessively large rivet sizes.

In very thin sheets, joint strength will tend to be limited by the bearing strength of the sheet, the theoretical size for rivet diameter being impractical. In such cases rivet diameter may have to be assessed on bearing strength requirements. Tubular rivets may be preferred to solid rivets in such applications.

Maximum bearing strength = Fb T D.

$$\text{Hence } D = \frac{FbT}{\text{bearing strength required}}$$

where Fb = maximum allowable bearing stress for the sheet material.



New Books

Third Congress of the Federation Internationale de la Precontrainte (International Federation for Prestressing). (*Cement and Concrete Association, £13 complete—£10 to members of affiliated groups.*)

Volume 1 contains the papers, which are printed in English, French, German or Spanish, with summaries in three other languages. Volume 2 is made up of the discussions, with lists of officers, committees and members of the Federation.

Prestressing is the artificial stressing of a member before it carries load, and, since the prestress is opposite to the load stress, it is reduced when the load is applied. In this sense, prestressing has for many years been applied to structures such as steel bridges, but only since 1945 has it been widely used in concrete.

Altogether 62 papers were presented to the Berlin Congress in 1958, 24 on design methods and 38 on practical construction; 21 papers were in English and 19 in German. The Federation was established in Ghent in 1951 on the initiative of the late Professor Magnel, one of the originators of prestressed concrete. The first International Congress was held in London in 1953 and the second in Amsterdam in 1955. The fourth is due to be held in Rome in 1962.

These books contain a mass of information which will for some years be indispensable to forward-looking civil engineers, whether they work for designers or contractors.

J. S. Scott

Machine Shop Estimating. *By W. A. Nordhoff. Second edition* (*McGraw-Hill, 70s.*)

Some five hundred pages liberally illustrated with diagrams and photographs make this manual a comprehensive survey of the estimator's technique, which, combined with time study, should prove of considerable assistance to tiro and veteran alike. The compilation of tabular data requisite to successful estimating is dealt with fully, and the slight repetition apparent in the opening chapters will serve to impress the fundamentals upon the reader, eliminating the need for back reference.

Ratios between materials, cutting speeds, etc., and time in decimal minutes are detailed in tabular form, embracing the majority of normal machining operations. In addition, complete breakdowns, including estimated times on each of the wide range of operations selected, are provided throughout, together with descriptions of the necessary machining processes.

The use of maximum available horsepower is not neglected, and chapter five goes to some length to explain some interesting formulæ on this subject. Not so, however, the section on the process of electrical discharge drilling, which could have been given more prominence owing to its development potential.

A. H. Roach

Theory of Mechanical Vibrations. *By Kin N. Tong.* (*John Wiley, Chapman & Hall, 78s.*)

This book is the outcome of lecture notes given by Professor Tong to post-graduates at Syracuse. Great use is made of inductive reasoning to examine combinations of free or forced, damped or undamped and one, two or several degrees of freedom. This method unfortunately suffers from lack of conciseness. The book is restricted to the study of linear vibrations and, as its title suggests, the approach is a mathematical one.

Chapter one develops the use of complex variables to explain types of motion with one degree of freedom. The case of a general external exciting force is treated by considering the indicial response of the system. Chapters two and three, which deal with two and several degrees of freedom respectively, are developed along lines similar to one another, but matrix algebra is used in the latter case. Elastic vibrations of beams, plates and membranes are treated in chapter four. Each chapter contains worked examples, but the unworked exercises suffer from having no answers provided. It is doubtful whether this book is suitable as a course text-book (as is claimed in the foreword), because no two lecturers ever choose exactly the same material and present it in precisely the same way. The main value is the presentation of the more advanced mathematical tools available to the vibrations specialist.

N. W. Murray

Low Temperature Techniques. *By F. Din and A. H. Cockett.* (*George Newnes, 40s.*)

This book clearly defines some of the practical aspects enabling low temperatures to be obtained, and outlines the problems of measurement, physical properties of materials and other valuable data. Cryogenics (coined from the Greek (Kryos), meaning icy cold, and genic (genes) to become or produce) was carried out in only a few universities and laboratories throughout the world until 1947, when a great upsurge took place.

More emphasis should have been given to the field of refrigerated low temperatures, as great studies have been made here, particularly in the simulation of flight conditions for missiles and high-speed and high-altitude aircraft. This volume, however, may be regarded as a most useful asset to all concerned in this field of activity.

V. A. Austin

The Manufacture of Iron and Steel: Vol. 3. *By G. R. Bashford.* (*Chapman & Hall, 35s*)

This volume has been compiled primarily as a text-book for the student and as a reference for the practising engineer, and is written in the same clear style as volume two (reviewed in our October issue, 1959). It covers basically steelworks' fuels, furnaces, refractories and instruments.

Fifth International Conference on Hot Dip Galvanizing. (*Zinc Development Association, 63s.*)

These proceedings of the Benelux International Conference of Galvanisers include papers by nineteen authors from eight countries. The papers are arranged in chapters covering: pickling and fluxing; bath heating; strip galvanising; painting of galvanised steel; wire galvanising; testing of galvanised coatings, and materials handling. There is also included a detailed survey of the galvanising process with particular reference to efficiency in the usage of zinc. Specialist galvanisers will be particularly interested in the papers on strip and wire galvanising.

Perhaps the most important section of general interest is that concerned with the oil firing of galvanised baths. The galvanising industry has been somewhat slow to adopt oil firing. This is due to the problems which arise from the necessity of absolutely uniform heating of the baths and the narrow margin of control required, and the fact that whilst a working temperature of 450 deg. C. is required, a rise of 30 deg. in any one point of the bath wall can cause rapid erosion and premature bath failure. Nevertheless, because of the potentially lower cost of this form of firing, the industry has a keen interest in the solution of these problems, and the papers and the discussion presented give a clear indication of the considerable progress that has been made in this field.

The extent to which costs can be dramatically lowered by improved methods of materials handling is shown by photographs and statistical work study charts.

J. S. Morley

Advanced Engineering Mathematics. *By C. R. Wylie. Second edition* (*McGraw-Hill, 70s.*)

Professor Wylie shows his readers around some sections of more advanced mathematics, the visits to the regions chosen being sufficiently long and embracing for the reader who stays the distance to find his own way around. The book is suitable for final-year and research engineers with a leaning towards the mathematical side of engineering. Topics covered are those usually selected for works of this nature, viz. vector analysis, Bessel functions, matrices, complex variable functions, etc. Both worked and unworked examples are presented, about half of the latter having answers given. The examples are only occasionally applied to specific physical problems such as vibrations, heat transfer and bending of beams. The author's style is clear and logical, and someone with a reasonably sound background of calculus could use this book for self-study. A comprehensive index is provided, and this edition differs from the first by the inclusion of more explanation at the expense of an appendix and a section on fluids.

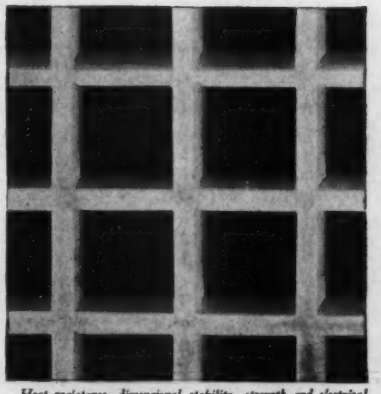
N. W. Murray

for heat resistance

special "thin-flash" type for grille moulding

Beetle D.M.C. is the material used for the grille of the Morphy-Richards Fan Heater because it offers high heat resistance and good appearance. The use of D.M.C. posed a flash-removal problem in relation to the many apertures, as the moulders, Crystalate (Mouldings) Ltd., specified a very thin flash line. Accordingly, B.I.P. Chemicals Ltd. developed a special type of material (D.M.C. L.1834) which, in combination with a tool made to close limits, ensures a consistently thin and easily removed flash.

Beetle D.M.C. combines heat resistance with strength, dimensional stability and excellent insulation properties. The development of a special type for a single application typifies the extent of B.I.P. services in relation to individual problems and requirements.



Heat resistance, dimensional stability, strength and electrical insulation properties are among the features making D.M.C. the ideal material for this grille. Moulding by Crystalate (Mouldings) Ltd., Tonbridge, Kent.

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B.I.P. Chemicals Limited, Oldbury, Birmingham. Phone BROadwell 2061
London Office: Haymarket House, 28 Haymarket, S.W.1. Phone TRAfalgar 3121

New Books (Cont. from page 508)

Molecular Science and Molecular Engineering. *By Arthur von Hippel.* (*Chapman & Hall, 148s.*)

This book has been compiled from contributions to a summer programme on molecular engineering held in 1956 at the laboratory for insulation research, Massachusetts Institute of Technology. The contributors, led by Professor A. R. von Hippel, have endeavoured to present both a background to research on materials, and an account of recent developments and applications.

The range of subject-matter is extensive and includes: conduction of electricity by gases, liquids, and solids; synthesis of polymers; growth of single crystals, and the properties and applications of ferro-magnetic and ferro-electric materials. Apart from a short introductory chapter, there is no account of dielectrics. These materials are described fully in the two earlier books of the trilogy which this book completes. There are chapters on the results of irradiating materials, the plasticity of crystals and the action of ion-exchange resins.

Although reactions in liquids and gases are described, there is no similar account of reactions between solids or of sintering processes. This is unfortunate, since many of the materials described in the text are notoriously difficult to prepare to an exacting specification. It is a fault of this book that the chemical difficulties associated with materials research are not emphasised, for often between the design of a material and its successful production there is much chemical analysis.

The description of the structure of atoms and molecules, written by the editor, is a successful condensation of a great deal of knowledge that owes much to the skilful use of diagrams and illustrative data. An attempt to treat thermodynamics, statistical mechanics and phase equilibria in a similar way is not so satisfactory. The chapters on ferro-electricity and ferro-magnetic phenomena are very good, and there is an excellent introduction to rectifiers and transistors.

Very full and up-to-date references are given in footnotes to the text, and are frequently qualified with an additional note. Each chapter is closed with an extensive classified bibliography. The whole book is lavishly illustrated with bold line graphs and diagrams, and there is a wealth of tabulated data.

A. A. Fuller

Progress in Semiconductors—Vol. 4. *General editor, Alan F. Gibson.* (*Heywood & Co., 63s.*)

Students and others will be familiar with the series "Progress in Semiconductors", three volumes having already appeared at intervals of roughly twelve months. In Volume 4 Dr. Gibson maintains the exceptionally high standards set in the previous volumes and, as before, the information is presented in the form of papers submitted by the most eminent exponents of the particular subjects.

Eight subjects are dealt with: negative effective masses in semiconductors; oxidation phenomena on germanium surfaces; theory of avalanche multiplication in non-polar semiconductors; internal field emission; noise in semiconductors; electrical effects of dislocations in semiconductors; dielectric properties of solids in relation to imperfections, and non-crystalline, amorphous and liquid electronic semiconductors.

Inevitably in a work of this nature there is some confliction of opinion between contributors as to how much the reader can be assumed to know already, but, generally speaking, a reasonable compromise is achieved and there is no undue labouring of information that can be readily obtained from standard text-books. The success of a publication of this nature is very much dependent upon intelligent editorship, and the editors of this volume are to be congratulated upon the way they have achieved an effect of homogeneity where less skilled hands might easily have allowed the work to degenerate into a mere collection of discrete opinions.

C. J. Foote

Liquid-metal Heat Transfer Media. *By S. Kutateladze.* (*Chapman & Hall, 180s.*)

A translation from Russian of supplement No. 2, *Soviet Journal of Atomic Energy*, 1958, this book contains extensive data from original Russian researches as well as selected items from work published in Europe and America. It is conveniently arranged, with thirteen specialised chapters, following a similar presentation to that used by McAdams.

In chapter one the relevant physical properties of mercury, sodium, potassium, etc., are summarised in individual tables. Chapter twelve gives comprehensive lists discussing the resistance of metals to attack by the liquid metals. The intervening chapters discuss heat-transfer properties during flow in tubes, around plates and cylinders, free convection, condensation and boiling. These data are presented in neat graphical form, with precise notes discussing the relationships in the general text. Standard non-dimensional grouping is used, e.g., Nusselt and Prandtl numbers, and the nomenclature is readily understood. A short chapter on instrumentation and a list of sources of material used concludes the book, which should become a useful work of reference for engineers and research workers.

R. W. New

The Oil Engine World Directory of Manufacturers. (*Temple Press, 7s. 6d.*)

This second edition gives the names and addresses of the principal manufacturers of diesel engines throughout the world, together with a brief summary of each individual engine. Explanations and a glossary of technical terms are given in English, French and German.

Plastics Engineering Handbook. *Third edition.* (*Reinhold, Chapman & Hall, 120s.*)

Compiled by the American Society of the Plastics Industry, this handbook includes definitions of terms, a classification of rigid moulding materials with their properties, and comprehensive chapters on the various moulding processes, preforming and drying methods and extrusion processes. Methods of fabrication, the design of moulded articles, the standards for tolerances, and mould and die design make this an almost essential book for the designer, who will find further valuable information from chapters on cementing, welding and assembly of plastics. Charts, diagrams and illustrations make this a most valuable publication.

British High-speed Diesels. *By C. Morgan-Jones.* (*Temple Press, 15s.*)

The modern high-speed diesel engine offers a serious challenge to the petrol engine, and this book explains in a practical manner the principles of the diesel without recourse to mathematics. It deals comprehensively with the various components and the chapter on "trouble shooting" is of particular interest. A book recommended for the practical man.

OTHER BOOKS RECEIVED

Insulation for Small Transformers. *By J. H. Mason and C. G. Garton.* (*Electrical Research Assoc., 37s. 6d.*)

Guide for Buyers. (*National Fed. of Engineers Tool Mfrs., 5s.*)

Powder Metallurgy No. 4. (*Powder Metallurgy Joint Group; member 10s. p.a.*)

Data Sheets on Moulding Sands. (*British Steel Castings Research Asoc., 30s.*)

Zone Refining and Allied Techniques. *By N. L. Parr.* (*Newnes, 40s.*)

Buyers Guide. (*"The Engineer", 7s. 6d.*)

British Plastics Year Book, 1960. (*Iliffe & Sons, 42s.*)

Design (data book for civil engineers). *Third edition, volume one.* (*J. Wiley, Chapman & Hall, 192s.*)

Symposium on Particle-size Measurement. (*American Society for Testing Materials, special technical publication 234, $6.25.*)

Statics of Soil Media. *By V. V. Sokolovski.* (*Butterworths Scientific Publications, 52s.*)

The Diesel Engine. *By L. V. Armstrong and J. B. Hartman.* (*The Macmillan Co., New York, 45s. 6d.*)

British Standards Yearbook, 1960. (*British Standards Institution, 15s.*)

The Analysis of Hyperbolic Paraboloid Shells. (*Timber Development Association Publication, 3s. 6d.*)

Annual Report of the British Iron and Steel Research Association.

The 1959 Supplements to the 1958 Book of A.S.T.M. Standards including Tentatives. *Part 1: ferrous metals (specifications); part 2: non-ferrous metals (specifications), and part 3: methods of testing metals (except chemical analysis).*

WHAT'S NEW IN MATERIALS & COMPONENTS

Wood Laminate

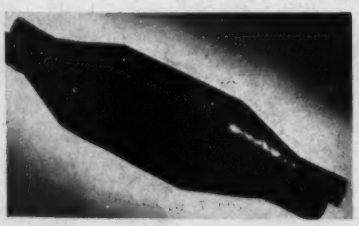
A medium-density, non-impregnated wood laminate called "Permawood" is now being supplied for use in transformers. Applications are confined to those which permit the material to be dried and subsequently impregnated under vacuum with oil or Pyrochlor, and typical examples include lead support bars, key strips and other parts subjected to tension, bending or torsional loads such as plates, blocks and parts loaded in compression or stressed in several directions.

Most of the development work on this medium-density wood laminate has taken place on the Continent, where it has now been used for many years for its high mechanical strength and product uniformity, a direct result of the lamination and densification process which removes the faults of natural timber and reduces the amount of trapped air. Free moisture content is said to be less than 7 per cent, a property which assists the drying-out process and causes less distortion and shrinkage compared with materials of a higher moisture content. The maximum standard board size is 84 × 48 in., with a thickness range of from ¼-3 in. Permali Ltd., Bristol Road, Gloucester.

EMD 3375 for further information

Epoxide Resins for Cable Jointing

A series of epoxide and polyester systems for cable jointing, claimed to have a number of technical and economic advantages over more conventional jointing

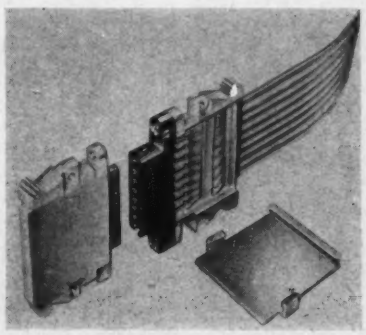


materials, is now being marketed. These epoxide resins are said to possess good adhesion to most surfaces, particularly to metal conductors, armouring and most types of tape and, when used in cable jointing compounds, to eliminate the need for site heating equipment. Because of the inherent strength of cast epoxide resins, simple moulds made from thermoplastic sheet, pulp or similar materials are adequate, thus obviating the use of metal joint boxes. The controllable quick-setting characteristics of these resins also make possible a quicker jointing cycle. A range of low-cost hardeners has also been introduced. Bakelite Ltd., 12-18 Grosvenor Gardens, London, S.W.1.

EMD 3376 for further information

Cable and Connectors

Flexistrip cable, introduced by Telegraph Condenser Co. Ltd., is made in the form of a flat, flexible, insulated ribbon containing a number of parallel copper foil strip conductors, each 0·075 in. wide and 0·0028 in. thick, spaced apart symmetrically and insulated from each other by polythene, and covered overall by layers of polyester film. A typical cable embodying five such conductors has an overall width of 0·95 in., a thickness of only 11·5 mil. and weighs 0·824 lb. per 100 ft. The instantaneous breakdown



voltage in water is 5·5 kV. at 50 c/s, and with each conductor carrying 2·5 amp. the temperature rise is 15 deg. C. in free air.

A new range of connectors has been developed for use with the cable. An identical housing is used for the male and female portions of the connector, and comprises a moulded body with snap-on lid. The body has a cable-entry slot in the rear face, and two further slots in the base through which the cable is threaded so that any pull on the cable imposes no strain on its terminations. The housing accommodates either a printed circuit socket, which is secured by self-tapping screws through the two mounting ears into the front face of the body, or a printed circuit board which constitutes the plug member and fits snugly into a box-shaped recess in the body moulding; this board carries a row of terminating lugs at its rearward end, projecting at right angles from the surface. The pre-pierced cable end is solder connected to these lugs or to the terminations of the contacts in the socket assembly. Belling & Lee Ltd., Great Cambridge Road, Enfield, Middlesex.

EMD 3377 for further information

Electrical Insulation

Quinorgo R-4 is a base sheet consisting of an integral combination of electrically pure asbestos fibre and woven glass cloth. Manufactured complete on a cylinder machine, it is an integral sheet capable of saturation with a wide variety of electrical-grade resins and varnishes. Some of the resins already used are polyester, silicone, alkyd, melamine, epoxy, phenolic and glyptal.

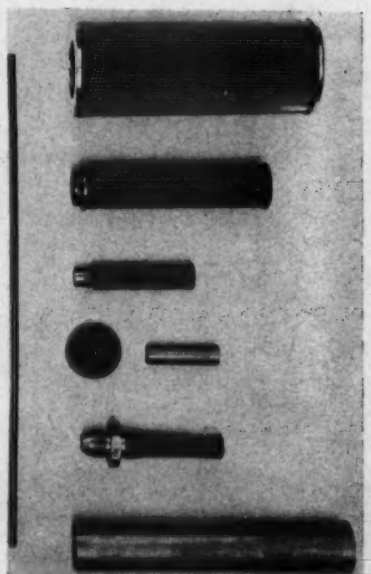
It is claimed that, with both glass cloth and asbestos fibres in the same sheet, designers are assured of thermal stability and resistance to acid and alkali attack. The asbestos fibres give the sheet heat resistance and economy, while the glass fibres provide strength and flexibility. Available in 10 mil. thickness for rotating equipment, it can be supplied in 36-in.-wide rolls, tapes and cut sheets. Johns-Manville Co. Ltd., 20 Albert Embankment, London, S.E.11.

EMD 3378 for further information

Filter Medium

A new filter medium, Poroloy, is said to guarantee 100 per cent protection continuously in critical conditions. Generally manufactured in 18/8 stainless steel, it is also available in other metals such as nickel-chrome, Inconel nickel or almost any metal that can be drawn in fine wire forms.

Filters are manufactured with inserts in the form of seamless porous tubes, flat sheets, pleated discs, pleated cylinders and many other forms made possible by the material's ductility and high strength characteristics. It is claimed that Poroloy can be readily welded, silver soldered or cemented, and that filter inserts can be designed to withstand differential pressures of over 3,500 p.s.i. without failure.



Operating temperatures range from −350 to 500 deg. F. according to materials and the construction of the filter. The nominal pore size ratings vary from 2 to 1,000 microns. Vokes Ltd., Henley Park, Guildford, Surrey.

EMD 3379 for further information

50,000

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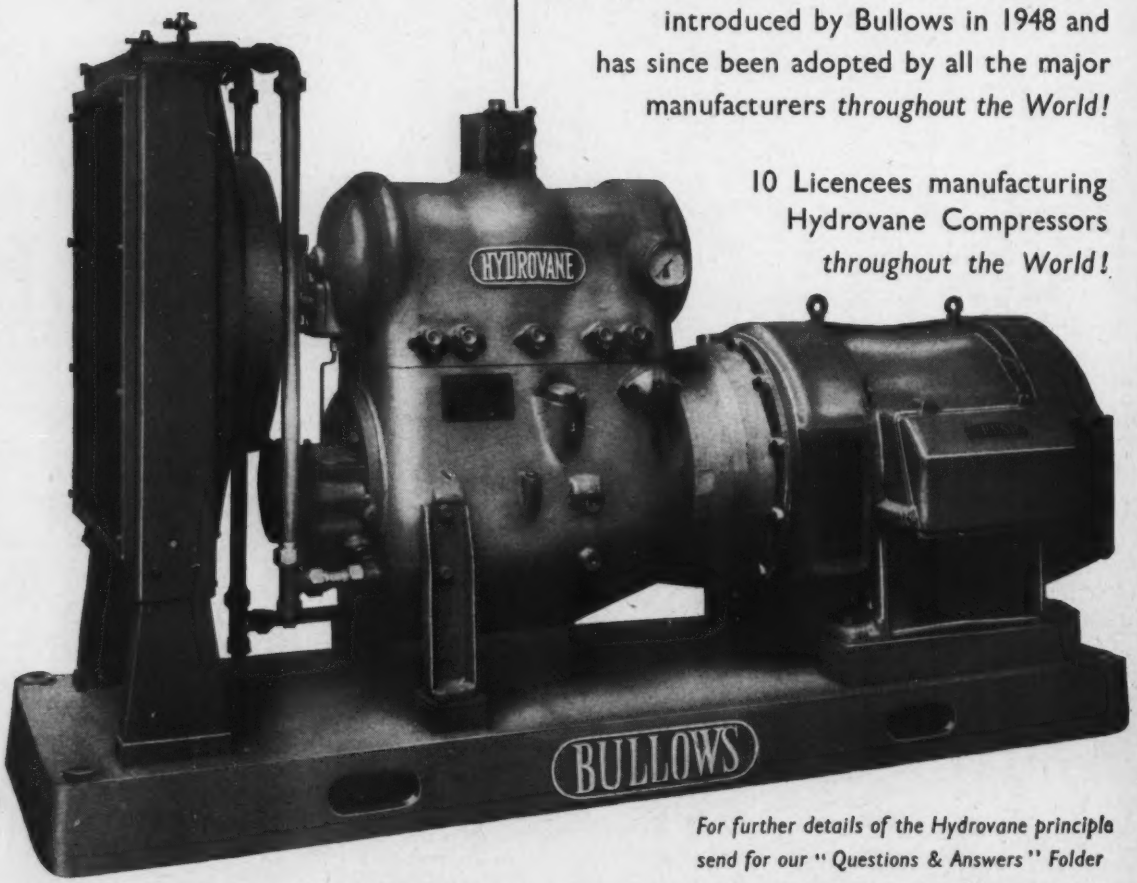

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Belt Dressing

Sprazon is a belt dressing designed to prevent slip and aid in preservation. It is supplied in a neat, portable container with a press-button, from which it may be sprayed on directly wherever slippage is occurring. Suitable for flat, V or round belts made of leather, rubber or textile, it contains no rosin or other harmful ingredient. Each 12-oz. container holds enough dressing to treat approximately 350 sq. ft. of belt surface. Graton & Knight Ltd., Warwick Road, Boreham Wood, Herts.

EMD 3380 for further information

Silicone Rubbers

Silcoset silicone rubbers can be cured at room temperature by the addition of one of two catalysts which are supplied with the product, and the curing time can be varied to suit the needs of the user. They are said to be excellent for sealing, patching, caulking and potting applications where extremes of temperature are ultimately to be encountered, and are also suggested for moulding silicone rubber parts where heat curing is undesirable, or when the cost of conventional rubber moulding equipment is not justified.

It is claimed that encapsulation of delicate electronic parts—"fly in amber" protection—is readily done with these new materials and that moulds for casting resins used in model reproduction and for low cost tooling can be easily made from them. When dissolved in a special solvent, the rubbers can be used to coat an extensive range of organic and inorganic fabrics for electrical insulation and anti-stick applications. Imperial Chemical Industries Ltd., Nobel Division, Silicones Department, Stevenston, Ayrshire.

EMD 3381 for further information

Stoving Enamels and Primers

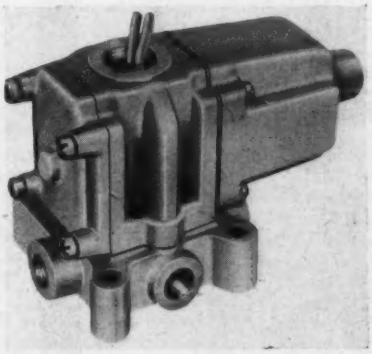
Aquakoat water-thinned stoving enamels and primers solve a number of problems sometimes associated with the conventional type of these materials. No special thinners and solvents are required, and the equipment, spray booths and supply systems used may be easily cleaned with water. Aquakoat is supplied for application by spraying or dipping, and is said to hold up well in dipping tanks with no loss of solvents due to evaporation, and no likelihood of skinning. Excellent adhesion, with good build, flow and gloss, is claimed, and it can be applied over damp surfaces. No emulsifying agents are necessary in water-washed spray booths and washings can be collected and used for thinning, resulting in little or no loss of paint due to overspray. Work spoilt before stoving can be cleaned off with water. R. J. Hamer & Sons (Paints) Ltd., Miles Road, Mitcham, Surrey.

EMD 3382 for further information

New High-speed Solenoid Valve

T.A.L. Numatics have introduced a new range of small valves which employ their "balanced spool-floating sleeve" valve action. Designed primarily for the control of small air cylinders, they will also operate medium-sized cylinders (up to 4-in. bore) where high piston speeds are not required. The valves are tapped for ¼-in. pipe and have free area equal to ¼-in. diameter hole. The 1SGA 4 valve is recommended for service on vacuum or air pressures to 300 p.s.i.

The balanced spool principle, without moving O-rings or elastic seals, enables 1SGA 4 valves to operate on a very low amperage—less than 0·5 amps inrush on 230 v. 50 cycles.



The unique solenoid capsule construction is claimed to permit rapid valve dismantling without loose parts. The valves are sub-plate mounted and there are two porting arrangements to suit any design requirement. T.A.L. Numatics Ltd., Leighton Buzzard, Bedfordshire.

EMD 3383 for further information

New Range of Vacuum Gauges

The redesigned "Metrovac" high vacuum gauges are claimed to be notable for an effective combination of features important in the designing of industrial and laboratory high-vacuum systems. The range includes ionisation, Penning, Pirani and thermocouple gauges covering the pressure range 10^{-9} to 1 mm. mercury.

The gauge heads of the new range are small and are claimed to be robust and demountable. They are metal encased, and have been specially designed so that wearing parts can be replaced at little cost. The elements can be replaced *in situ* quickly and easily. Each control unit gives a direct reading. Associated Electrical Industries (Manchester) Ltd., Trafford Park, Manchester, 17.

EMD 3384 for further information

Unit Construction Hydraulic Pump

For the requirements of mining and general engineers who need a high-pressure pump of very small capacity, a new design of high-speed hydraulic pump is announced.

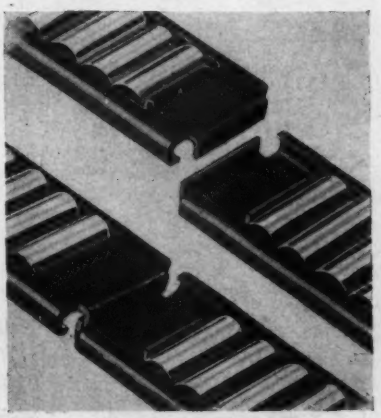
The pump is of unit construction and is available with from three to six cylinders. Each cylinder has an output of 0·6 gal./min. and a six-cylinder unit would have an output of 3·6 gal./min. Delivery pressure is 1,000 p.s.i. The eccentric shaft of the pump, which is mounted on roller bearings, is coupled directly to the motor, which runs at a synchronous speed of 1,000 r.p.m. through a flexible coupling.

The pumps are suitable for operation with water, water-soluble oil mixture or hydraulic oil as the working medium and the design can be adapted for use with other liquids. The units can be provided with spring-loaded relief valves, or alternatively with automatic unloading valves which enable them to run light when operating against closed stop valves. Joseph Evans & Sons (Wolverhampton) Ltd., Culwell Works, Wolverhampton, Staffs.

EMD 3385 for further information

Needle Roller Tracks

Nadella needle roller tracks have been specially developed for use in machine slideways and in other applications where linear and reciprocating motions are involved. They are designed to transform sliding friction between two plane surfaces into rolling friction and thereby eliminate the "slip-stick" phenomenon. This is particularly important in tape- and data-controlled automatic machines. The tracks

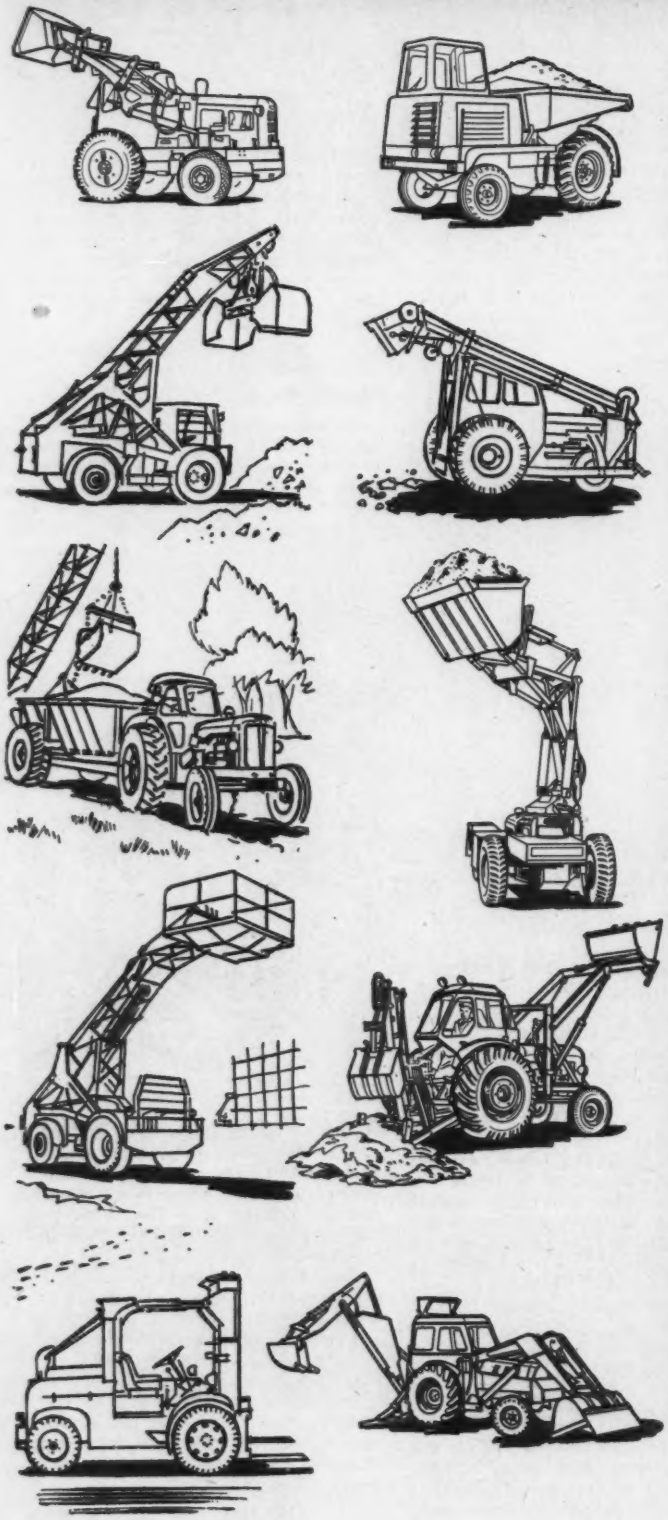


consist of a group of trunnion-ended needle rollers enclosed in a cage of heat-treated steel. The needles are highly finished and held to a tolerance of 2 microns (0·00008 in.). The cages have hooked ends so that they may be linked together to form any desired length.

These compact anti-friction components are claimed to have a high load capacity when mounted on hardened raceways, but for light duty and non-precision applications they may be used on cast-iron or unhardened steel surfaces. They are made in two sizes, 30 x 11·3 mm and 48 x 17·8 mm., and can be used in horizontal, vertical, inclined or dovetail slides. Insley Industrial Supply Co. Ltd., 21-22 Poland Street, London, W.1.

EMD 3386 for further information

EXPERIENCED OPERATORS INSIST ON



FORDSON POWER

Men who have kept to the tightest schedules in the toughest conditions; men who have manned machines working round the clock, seven days a week; these are the men who know from experience that for proved reliability Fordson Power is unequalled. Add to reliability all the other Fordson advantages of high output, low costs, unrivalled service and spare parts organisation, and almost unlimited choice of build-ups in the 30-40 and 40-50 b.h.p. classes. That's why more Fordson power units than any other are used in industrial equipment. Write for detailed specifications.

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Compressed Air Filters

A range of small compressed air pipeline filters is now available with alternative elements giving two degrees of performance. They have been specially designed to give maximum protection to air-using equipment by the continuous removal of abrasive pipe scale and other solids and corrosive moisture from the supply air.

The standard general-purpose element is the VAF.57 and it is suitable for applications where removal of water or oil mist and grit is required, but where the concentrations are average. The alternative element, the "D" Pak, is for applications where oil or water mist removal is of primary importance and a high degree of purity is essential. Both elements are interchangeable within the standard case.

A die-cast light alloy head-casting houses the filter element, which can be removed by unscrewing one nut. A ribbed clamp ring mating with a thread on the head is employed to fit a transparent bowl which is available in two capacities. The standard unit is capable of operating at pressures up to 150 p.s.i. Units for operation at pressures in excess of this and up to 250 p.s.i. are supplied in metal.

The filters are suitable for pipelines of ¼-in., ⅜-in. and ½-in. diameter. Vokes Ltd., Henley Park, Guildford, Surrey.

EMD 3387 for further information

Worm Gear Jacks

The Duff Norton 1800 series of worm gear jacks consists of eight units with capacities of from 2 to 100 tons. They have been designed for building into machinery and equipment where jacking duties are involved. Being mechanical in operation, the jacks can be connected by means of shafting and mitre gearboxes to lift in unison, even, it is claimed, with an

unevenly distributed load. Being self-locking, they can be used to hold loads of several hundred tons in position indefinitely without creep occurring.

The jacks use phosphor-bronze worm gear teeth and are fitted with Alemite grease nipples. No keys are fitted in the lifting screws and this allows the top to be bolted to the member being raised, thus preventing the jack from turning. A clockwise rotation is used for lifting the load, the maximum worm gear speed being 500 r.p.m. In the smallest and two largest jacks in the range a ball race and grease seal are fitted at each end of the worm, while for jacks of from 5 to 25 tons capacity Timken taper bearings are used for this duty. The closed height of the range lies between 5¼ in. for the 2-ton model and 24 in. for the 100-ton unit. The base measurements increase in eight stages, according to the size of the model, from 3¼ × 7 in. for the smallest jack to 20¾ × 24¼ in. for the largest unit. Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6.

EMD 3388 for further information

Centrifugal Air Compressor

Designed to furnish air at 100 p.s.i. for oxygen plants, centralised air systems and other industrial air applications, a new high-efficiency multi-stage centrifugal air compressor is announced. Designated the Clark H line, the new series features integral inter-coolers between each stage of compression for highest possible efficiency. Six case sizes are available, with horsepowers ranging from 1,000 to 8,000 b.h.p. and capacities from 5,000 to 38,000 cu. ft./min. Each unit is furnished as a complete package including matching driver, intercoolers and lubricating system.

By careful attention to the design of the intercooling system, plus the new volute and impeller designs, it is claimed that extremely high compressor efficiency has been achieved. Single case construction plus base mounting of the intercoolers is said to cut floor space requirements as much as 40 per cent over machines of comparable horsepower. Bearing supports are cast integral with the case, and back-to-back impeller design is claimed to provide inherent thrust balance, thereby eliminating the need for a thrust balancing device. A double thrust bearing absorbs any residual thrust load and accurately locates the shaft axially.

The use of isolated bearing chambers plus a unique seal porting system eliminates lube oil contamination of the compressed air stream. External oil or mist extractors are claimed to be unnecessary. The compressor can be supplied with an induction or a synchronous motor, or can be adapted for other types of prime mover. G. & J. Weir Ltd., Cathcart, Glasgow, S.4, Scotland.

EMD 3389 for further information

Wade Couplings Ltd.: We regret that on page 451 of the July issue the diagram showed a nylon tubing joint, instead of a self-sealing coupling as was intended.

New Publications and Technical Literature

The Telegraph Construction & Maintenance Co. Ltd.: Two illustrated brochures—(1) describing Telcon injection moulding equipment and techniques for making joints in plastic cables; (2) dealing with Telcleats, which provide a means of fixing circular-section cables up to 2-in. diameter to a variety of surfaces. Mercury House, Theobald's Road, London, W.C.1.

EMD 3390

Turner Bros. Asbestos Co. Ltd.: Two catalogues dealing with the company's belting products—(1) "Rubber Conveyor Belting", giving details of the available range of natural and synthetic fibre, rubber-covered conveyor belts, and also information on belt installation, operation and maintenance; (2) "'Poly-V' Drives", containing engineering data on the service factors, horsepower ratings, pulleys and installation and maintenance instructions for this power transmission drive. P.O. Box 40, Rochdale.

EMD 3391

Keith Blackman Ltd.: Twenty-eight-page booklet with illustrations, dimension drawings and capacity tables covering three types of Tornado solid p.v.c. fume-removal fans. Mill Mead Road, London, N.17.

EMD 3392

Tyrad Electric Ltd.: Six-page leaflet giving full details of the Tyrad embedded system of heating floors by electricity, and describing a new former for retaining the heating cables in position during installation. Imperial Court, Basil Street, Knightsbridge, London, S.W.3.

EMD 3393

Hadfields Ltd.: Leaflet giving full details of Hecla 174 chromium steel. The outstanding feature of this material is its ability to withstand thermal cycling without the occurrence of the crazing associated with heat shock. East Hecla Works, Sheffield.

EMD 3394

A. E. Griffiths (Smethwick) Ltd.: Leaflet giving details of a range of direct gas-fired air heater units, suitable for all cases where an air temperature of up to 300 deg. F. is required.

EMD 3395

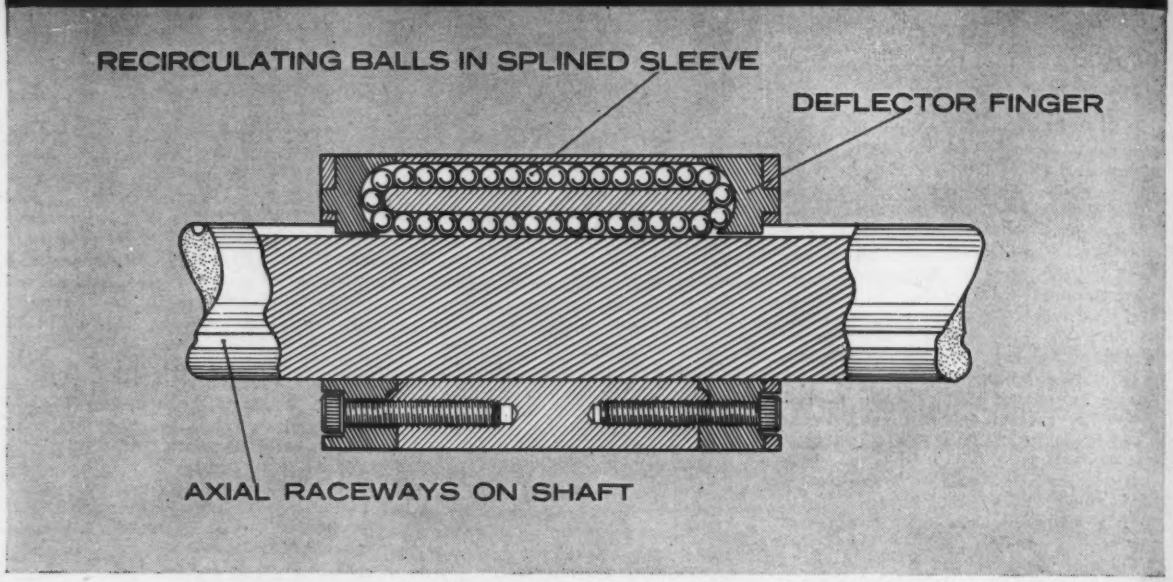
Organisation for European Economic Co-operation: Booklet (128 pages) entitled "The Demand for Engineering Products in Less Industrialised Countries—Studies on Latin America and India". This publication comprises, in the main, two pilot reports prepared by the machinery committee of the O.E.E.C. The Secretary, Machinery Committee, O.E.E.C., 2 rue Andre Pascal, Paris, 16ème.

EMD 3396

Stephens Belting Co. Ltd.: Illustrated brochure describing the firm's new works at Shirley, and the improved version of the Miraclo nylon and chrome leather belt which is to be made there.

EMD 3397

Beaver ball splines, over 90% efficient, operate at -55°C to 450°C and over . . .



. . . ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* ball splines. These ball splines achieve a minimum efficiency of 90% and they can operate within a temperature range of −55° C to over 450° C.

Machined and ground to the highest standards of precision, Beaver ball splines are much more efficient in operation than conventional splines. They substitute a recirculating stream of precision-ground balls, rolling along specially contoured grooves, for the solid key and keyway. This arrangement reduces friction to a minimum when the spline assembly is subjected to linear, torque and bending loads. It also gives optimum smoothness and a very fine degree of positioning accuracy. When compared to conventional spline mechanisms, Beaver ball splines require a much smaller power source; provide a predictable operating life; need much less maintenance; and give long trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification and each unit is specially designed for its particular application. For Beaver splines can be made with angular pre-loading, with multiple circuits, and with telescopic extensions. Beaver splines have been proved as the most efficient method of minimising friction when high torsional and bending loads are imposed during linear movement in many engineering applications. They have been designed already with rated operating torque capacities of 50,000 lb/in (200,000 lb/in maximum static torque) but the maximum potential operating torque is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball screws

reduce the power required for actuation by as much as 80%. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion when converting rotary drive into linear output.

**Complete technical and manufacturing co-operation with Beaver Precision Products Inc, Detroit.*

For further information please write to J. B. Starky, Sales Manager, (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

Bench Winding

A new bench-type winding machine complete with meter and drive, and a total dimension of approximately 24 in. long × 24 in. wide, is now being manufactured.

The machine, which is fitted with a five-figure reset revolution counter, can be designed with any value of maximum speed up to 4,000 r.p.m. The rate of acceleration from zero to maximum speed is determined by means of a plastics handwheel on the front of the machine which operates a potentiometer controlling the Warner electric clutch coupled to the motor.

Coils can be wound up to 5 in. diameter and 3 in. in length in gauges from 30-50 S.W.G. The reel carrier spindle is suitable for reels up to 6 in. diameter, but for the winding of fine gauges from 47-50 S.W.G. a small "over end feed" is also supplied.

The traversing mechanism incorporates two Warner electric brakes coupled to two worm wheels in constant mesh with two lead screws. The traverse is set by means of adjustable stops which actuate microswitches energising and de-energising the brakes, giving positive and instantaneous reversal of direction.

The wire spacing (turns per inch) is set by means of a handwheel moving against a calibrated scale engraved in s.w.g. sizes or in decimals of an inch. Westool Ltd., St. Helen's Auckland, Co. Durham

EMD 3398 for further information

Hygrometer

About half scale on the dial of the latest

Shaw hygrometer represents the practical limit of previous measurements of dewpoint. The other half (−70 to −120 deg. C.) is expected to be most useful in many industries, as the latest type air and gas driers using molecular sieves now dry down to −107 deg. C. dewpoint. Shaw Moisture Meters, Rawson Road, Bradford 1.

EMD 3399 for further information

Circuit Tester

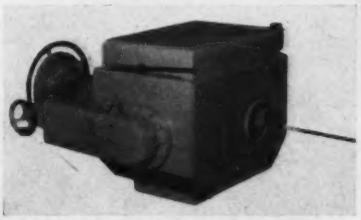
Now being marketed in the U.K. is the Robotester, which is an automatic instrument designed for the rapid testing of resistance, insulation resistance and a.c. or d.c. voltage between any two of up to 250 circuit test points. The sequence of testing is fully automatic, the ranges, tolerance limits and test point locations being controlled by means of a paper tape which is punched in accordance with the desired, pre-arranged programme.

60 to 100 tests per minute can be made, and any wiring or assembly errors and their exact location are indicated on an illuminated display on the front panel. When this occurs, the machine stops until given the signal to proceed. If required, the fault results can be recorded on an additional print-out unit which automatically gives the "proceed" signal as soon as the fault is recorded. Optional accessories include multiplier units to increase the number of available circuit points to 500 or 1,000.

It is claimed that, using this unit, it is possible to cut final test times on production equipment by as much as 80 per cent, and that special test jigs and plug boards can be completely eliminated and the number of test personnel greatly reduced. Metrix Instruments Ltd., 54 Victoria Road, Surbiton, Surrey.

EMD 3400 for further information

Mobile Betatron



The Siemens 15-MeV mobile betatron comprises essentially an electromagnet shaped in the form of a shell-type transformer which contains an air gap in its middle leg. The function of this a.c. excited transformer is to create a magnetic flux in which electrons are accelerated almost to the speed of light in a doughnut-shaped accelerator tube which surrounds the electromagnet. This accelerator tube is constructed of a ceramic known as frequenta, the inner wall being coated with a metal film. It is sealed by a 30-micra-thick nickel foil, through which electrons accelerated in the flux by a magnet may leave if the production of free electrons is required. For X-ray work, however, these electrons are arranged to graze a platinum target which is fixed to the inner wall of the tube, the resultant X-ray beam being taken out through the frequenta wall of the tube without a window.

The betatron is operated from a small, portable control case, and with a total weight of under 3½ tons it may be readily transported by truck from site to site. Substantial savings in exposure time are claimed with this new tool—for example, exposures for steel thickness of between 6 and 8 in. are only a few minutes, whilst that for a 16-in. thickness of steel is between one and two hours. Apart from this saving, a new technique of radiographing a workpiece whilst it is still hot is opened up, and since the cooling-for-examination stage is one where flaws may develop the elimination of this stage in thick section fabrication is expected to lead to the prevention of costly flaws in this type of work, as further fabrication can follow inspection without the need for a fluctuating temperature gradient. An additional point of note is the fact that a magnification technique giving an image of up to three times the size of the flaw can be used. Pantak Ltd., Vale Road, Windsor, Berks.

EMD 3401 for further information

Portable Thermometer

The Mavotherm is a portable instrument for the measurement of tem-

peratures in solids, liquids or gases. Suitable for use in both laboratories and workshops for rapid, accurate measurement of ambient or static temperatures, it is said to combine accuracy and speed with safety and convenience. A reading time of between 3 and 4 seconds and an accuracy of ±2 deg. C. are claimed.

The instrument is battery operated, and under normal load conditions its 1·5-volt battery will last for nearly a year. It has two ranges, −20 to +90 deg. C. and 90 to 200 deg. C., and two calibrated probes specially designed for easy access to difficult locations are supplied. The whole instrument is contained within a strongly made plastic case. Aveley Electric Ltd., Ayron Road, Aveley Industrial Estate, South Ockendon, Essex.

EMD 3402 for further information

FOR MORE INFORMATION
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EMD 3320 for further information

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EMD 3321 for further information

News of Industry

In the range of new machinery made by **British Industrial Plastics Engineering Ltd.**, the dual-purpose 32-oz. capacity 600-ton press is described as a new conception in plastics manufacture. The injection assembly of the machine consists of hydraulic power cylinder, hopper, feed, block and plasticising chamber. The plasticising chamber embodies some new ideas, the spreader being designed in one piece with the front cap and the surfaces in contact with the thermoplastic material fluted to permit maximum heat transfer. Each individual flute presents a diminishing cross-sectional area with a resultant skin purging of the material. Adequate heating is ensured by positioning heat elements together with a controlling thermocouple in the spreader, and conducting elements around the outside surface of the plasticising cylinder. A number of control features have been introduced to allow precise heating, cycle setting and material feed. The new, fully-automatic 20-ton compression press is the smallest of a family that comprises 150, 80 and 60-ton automatic machines. The 20-ton press incorporates most of the basic features of the bigger machines, but some modifications have been introduced to reduce cycle time and simplify production costs.

A four-day International Sales Conference was recently held by **Dewrance & Co. Ltd.**, and in support of this the company arranged a special exhibition, displaying their range of products, which included the Microsen process control system, the Asco solenoid valves and a new design of Jones Tate actuator.

Parkinson Cowan (Metropolitan Leather Co. Ltd. Division) anounce that they are shortly to open a new diaphragm testing and research laboratory. The research programme includes investigations into the use of polymer as diaphragm material, and testing new products so thoroughly that the need for subsequent field trials is virtually eliminated.

In June 1961 the **Construction Equipment Exhibition** will be launched at the Crystal Palace. A new company, Construction Equipment Exhibitions Ltd., has been formed to sponsor and promote the project, while the organisation of the exhibition will be carried out by **Industrial & Trade Fairs Ltd.** The latter firm have also arranged the British participation at the Sydney Trade Fair in Australia from August 1 to 12, 1961.

Toledo Woodhead Springs Ltd. have acquired the light coil spring section of John Spencer & Sons (1928) Ltd. A new company has been formed, and the light coil spring business will now be carried on under the style of **John Spencers (Light Springs) Ltd.**

Britain's first completely automatic heat-treatment line for carburising, annealing, hardening and tempering has been installed by **AEI-Birlec Ltd.** at **British Timken's** Daventry East Works. The equipment was built primarily for the heat treatment of tapered roller bearing cups and cones for vacuum brake rolling stock. By the correct selection of quenching operations with these continuously operating atmosphere furnaces, it has been possible to minimise the formation of scale on components during heat treatment and there is no necessity for any form of shotblasting operation. Furthermore, by incorporating washing, rinsing and drying operations, degreasing of components has been avoided.

Aluminium sheet 0·036 in. thick, made by **Northern Aluminium Co.**, has been used to clad a 30-in. bore steel steam main and some 1,300 ft. of smaller-bore branch pipes to give maintenance-free protection from the weather. Aluminium was used by **Thomas Cotton Ltd.**, the insulating engineers, because it is economical and easily worked, and on the largest pipe the cladding weighed only a little over 4 lb. per ft.—its lightness enabled savings to be made in the supporting structure. Lengths of coil were cut to wrap the steam main circumferentially with a 2-in. overlap joined by "pop" rivets.

The General Electric Co. Ltd., in association with **Vacuum Industrial Applications Ltd.**, has received an order from the British Steel Castings Research Association for a vacuum melting and casting furnace. The furnace is to be used for research into the melting and casting of steels under vacuum, and is capable of melting 56 lb. of steel. The working pressure of the furnace chamber is 1 micron Hg and a working temperature of up to 1,700 deg. C. can be achieved. Two dip thermocouples are provided for temperature measurement, and alloying additions are carried in six tipping buckets selected by a rotary indexer.

The Coil Spring Federation Research Organisation now has a liaison officer to improve communication between laboratory and factories, and to emphasise to industry generally the value of spring research.

The new four-strand continuous-casting plant which **Distington Engineering Co. Ltd.** are to build and install at **Appleby-Frodingham Steel Co.**, Scunthorpe, will be equipped to cast strands 9 in. square, and is scheduled to commence operation in December 1961. Liquid steel will be poured from the ladle into copper moulds, and after leaving the spray cooling chamber the solidified blooms, withdrawn by rolls, will be cut off vertically into 30-ft. lengths and discharged at ground level.

A unique illuminated aluminium handrail has been built by **Saunders-Roe Structures Ltd.** for the new Onikan Bridge at Lagos. In the main, aluminium extrusions are used in the construction of this handrail, each section being 16 ft. long—the main stanchions contain steel inserts for grouting into concrete. Each section is

complete with all the necessary wiring ready for connection to the main electrical supply, no cutting or jointing being necessary to complete the circuits. The fluorescent tube is sited in such a position that it does not dazzle the oncoming motorist.

The recent installation of a three-roll cold plate bending machine at the Erith Works of the **General Electric Co. Ltd.** enables mild-steel plate up to 4¼ in. thick to be bent. This is believed to be the largest machine of its type in this country, and its installation will permit rolling of the thickest plate likely to be encountered in pressure-vessel work.

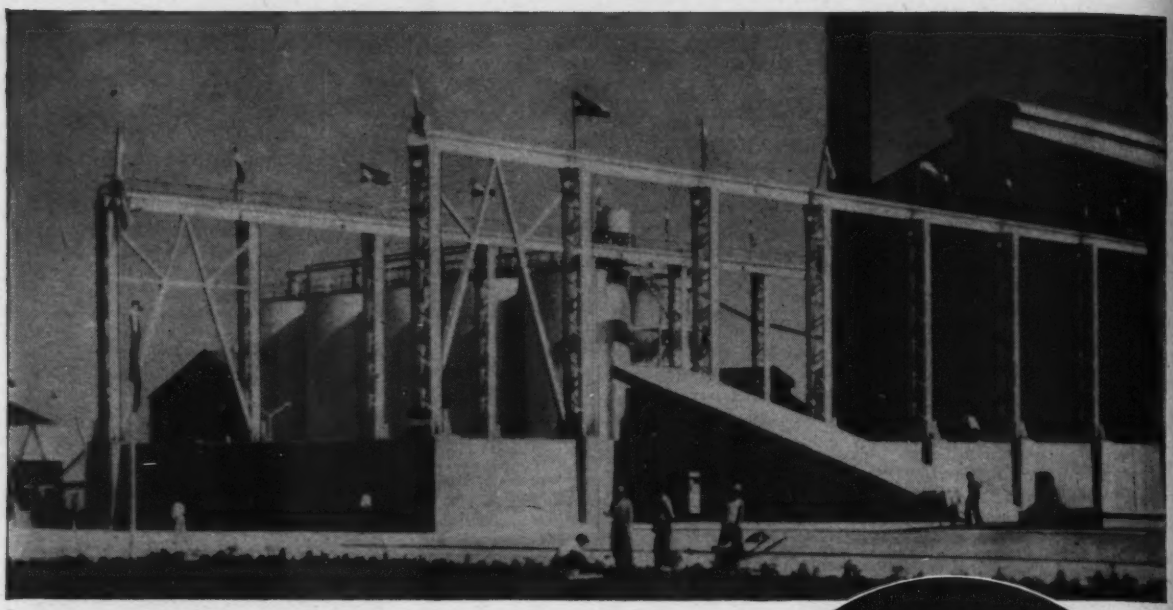
Two new divisions of **Head Wrightson Processes Ltd.** have been formed: Industrial Furnace Division to handle principally furnaces but also other items of heating equipment, and Water Treatment Division formed to handle a complete range of water treatment equipment.

The general method of starting the larger marine type diesel engines is by direct injection of high-pressure air into the engine cylinders; the high torque thus produced gives rapid acceleration until the speed when fuel can be introduced and ignited is reached. This is the system for which the **Hymatic Engineering Co. Ltd.** have developed a compressor, distributor and cylinder head valves.

FILMS

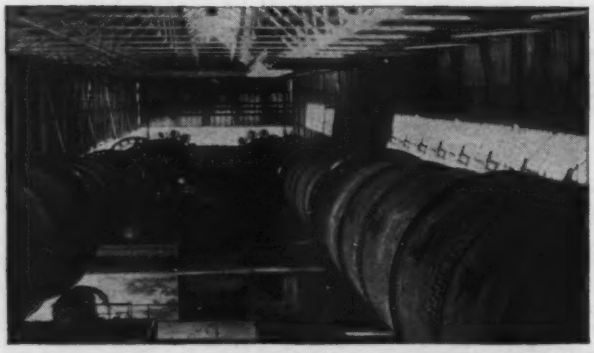
The Mobil Oil Co. have added two further industrial films to their library. The titles are *Textile Machinery Lubrication* and *Gears and their Lubrication*. Copies are available on loan.

Tufnol Ltd. have recently produced a colour film called *Tufnol in the Making*, copies of which are available on loan.



New Cement Works in Iran

MECHANICAL PLANT *manufactured and erected by* **EDGAR ALLEN & CO. LIMITED**



The area around Doroud in Iran is rich in raw materials, and those for the manufacture of cement lie conveniently close at hand. Here Edgar Allen & Co. Limited have supplied the country's most modern cement plant which has a capacity of 600 tons of Portland Cement per day. By a combination of engineering skill and metallurgical knowledge, we design and manufacture all the machinery for the efficient and economical production of cement from the processing and crushing of raw materials to the despatch of the finished product.

Messrs. Henry Pooley (Consulting Engineers) of London were the Consultants.

Have you had our publication: "Choosing a Cement Plant"?

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